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COMPARISON OF THREE SCIENTIFIC TRENDS IN RESOLVING GENERAL QUESTIONS OF SOIL CLASSIFICATION

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Soil literature of the world today contains a vast amount of material on soil classification which is extremely diversified in subject matter, scientific principles, and proposed theories. Consequently, a thorough and detailed systematization of such data is imperative for an objective analysis aimed at establishing points of similarity among different scientific trends in soil classification and nomenclature in various countries. Inadequate mutual understanding in this field of science considerably hinders the proper application and generalization of scientific soil data on a universal scale, and constitutes an obstacle to the full realization of an international community of soil scientists and to the exchange of their theoretical concepts and practical experience.

In this article we shall attempt to examine, in brief, the theory behind and the interrelationship of the Soviet (Russian), Western European, and American trends in resolving soil classification questions. Although not representing all of the existing schools of thought in soil science, these three trends are the most prevalent.

We shall begin our study with the Soviet (Russian) scientific school of thought. As is known, the initial principles for the present-day classification structure of soils were introduced in Russia by Dokuchayev and Sibirtsev (20, 44) who established the existing soil nomenclature by combining the popular name of the soil (by its color) with some geographic or genetic term. These principles are the direct result of Dokuchayev's interpretation of soils as specific natural historical formations which have been created under the combined influence of a specific complex of natural factors -- the soil formers (climate, parent material, topography, plant and animal organisms) and the human factor. As a result, the division of genetic soil groups into basic units in soil systematics has always been recognized in Dokuchayev's Russian soil science as the basis for constructing a genetic classification (i. e., a classification which is the result of the soil formation method). At the same time, the development and character of genetic soil groups have been based upon an analysis of a complex of the most important interrelated soil properties (structural soil profile, nature and stage of development of genetic horizons, composition and distribution of various organic, mineral, and organic and mineral substances, level of natural fertility, etc.). These had been considered as the result and outward expression of the soil-forming process developed under the cumulative effect of a combination of soil forming factors specific for each genetic soil group (i. e., under specific conditions of climate, parent material, vegetation, topography, etc.).

Sibirtsev (44) has clearly formulated the initial scientific principles of soil classification in Russian (Dokuchayev's) soil science by stating that "in setting up the principal soil groups, we should recover the types of soil formation or soil origin existing in nature, formulate those combinations of natural conditions which lead the soil-forming process in a specific direction towards a result which is well-defined and fixed in its principal characteristics." Proceeding from such a concept of the nature of the classification problem in soil science, such groups as the podzols of the taiga (coniferous) forests, gray forest soils of the deciduous forests, steppe chernozems, dry steppe chestnut soils, brown soils of the semi-desert, krasnozems and zheltozem soils of the subtropics, solonetzes, solonchaks, etc., have been divided in Russia into separate genetic soil groups and basic soil classification units. In addition, research on the division and character of the genetic soil groups in Russia, subsequently the USSR, begun by Dokuchayev and Sibirtsev and conducted by their pupils and co-workers, continues to the present day. As a result, the original composition of genetic soil groups established by studying, chiefly, the central and southern sections of European Russia has been continually expanded. Thus, for example, in studying the desert and mountain soils of Central Asia the separate genetic sierozem soil groups (34, 41, etc.), and the gray-brown and takyr soils (7, 11, 18, 19, 31, 33, etc.), have been divided; a study of the soils of the Caucasus and Crimea has resulted in a division of the mountain-meadow soils (Alpine meadow soils) (22, 32, etc.), cinnamon-brown soils (9, 23, etc.), and gray cinnamon-brown soils (42); while an investigation of the soils of the Urals and Western Siberia has led to a separation of the secondary podzolic soils (21, 25), acidic nonpodzolic forest soils (26), meadow chernozems (8) and several others.

We should by no means consider research on the development and character of prevailing genetic soil groups in the USSR as complete. Recent soil and geographic research in the Arctic, East Siberia, and the Far East reveals that profound peculiarities in the physico-geographic conditions of soil formation in these areas are responsible for the development of very specific soil processes together with the formation of original, independent, genetic soil groups, distinct from those set up earlier. Consequently, the total number and composition of the prevailing genetic soil groups in the USSR are continually increasing, while the basic classification schemes continue to be developed (see Tables 1, 2 and 3).

At the same time, we should point out that Soviet research on soil classification is not limited to the development and study of genetic soil groups, i. e., to the continuation of the work begun by Dokuchayev, although his work has been and continues to be used as a basis for all other classifications studies.

Socialist agricultural practices in the USSR have called for a thorough study of the country's available lands together with preparation of detailed soil maps, which require detailed soil classifications with a division of those fine subdivisions (in the taxonomic sense) as used in agriculture. Such an important practical consideration posed a new problem for soil science, namely, that of the transition from a more or less large classification unit -- the genetic soil group -- to considerably finer systematic subdivisions. Hence, the need arose to establish taxonomic units under the soil group, i. e., subgroups, genera, species, as well as types and sub-types (Prasolov 40, Gerasimov, 11, 12).

Thus, for example, the concept of "subgroup" was used to divide those soil formations (within the genetic soil group) which possess, in addition to the most characteristic properties of the group, important transitional (to other groups) properties, for example, the sod-podzolic soils (transitions from gray forest soils to podzol soils), podzolic chernozems, etc.

It was proposed to use the concept "genus" for developing (within a subgroup) the most important local characteristics (principally associated with the properties of the parent materials) in the soil formation process (formation of the humo-illuvial horizons within the subgroups of podzolic taiga soils on skeletal rocks, etc.). Finally, it was decided

Table 1

Soil classification
(by V. V. Dokuchayev (20))

	Class A	Normal (Vegetative-terrestrial or zonal soils)					
Zones	Boreal (Northern)	Taiga	Forest Steppe	Steppe	Desert Steppe	Aerial or Desert Zone	Subtropic and Tropic Forest
Groups	Tundra (dark-brown soils)	light-gray podzols	Gray and dark-gray soils	Chernozem	Chestnut and brown soils	Aerial soils. Zheltozem white earth, etc.	Lateritic soils or Krasnozem
	Class B	Transitional Soils		Class C		Abnormal Soils	
Groups	Surface-bog or bog-meadow soils	Carbonate or rendzinas	Secondary Solonetz	bog soils	Alluvial soils	Aeolian soils	

Table 2

General classification scheme of soils
(by Ye. N. Ivanova and N. N. Rozov, 27)

Soil Classes	Soil-formation groups (soil-sub-classes)	Soil groups[a]		
		Automorphic	Automorphic-Hydromorphic	Hydromorphic
	I. World group classes of northern soil formation			
Class I-Arctic tundra soils	1. Arctic-tundra	Arctic soils	--	--
		Tundra soils	--	--
	2. Subarctic sod	Sod soils	--	--
	3. Bog-tundra	--	--	Tundra-bog soils
	4. Arctic Solonchaks	--	Solonchak-arctic	--
Class II-(boreal) northern frozen taiga soils	1. Frozen-taiga	Taiga ferrous soils	--	--
		Pale yellow taiga soils	Pale yellow taiga soils	
	2. Frozen-bog	--	--	Frozen bog soils
	3. Frozen Solonetz	Frozen solodi	Frozen gley solodi	--
Class III-(boreal) northern taiga and forest soils		Podzolic soils	Podzolic-bog soils	--
	1. Forest-taiga	Gray-forest soils	Gray forest gley soils	--
	2. Sod-taiga	Sod-taiga (including sod-carbonate)	Sod-gley soils	--
	3. Bog	--	--	Bog soils
Class IV-Subboreal humid forest and meadow soils	1. Brown earth	Humid forest acidic non-podzolic soils	Humid forest acidic non-podzolic gley soils	--
		Brown forest soils	Brown forest gley soils	
	2. Meadow-brown	?	Meadow-brown earth soils (Prairie) ?	?
	3. Sod humid-forest	Humic-carbonate[b]	Humic carbonate gley soils	--
	4. Bog	--	--	Bog soils
Class V-Subboreal steppe soils	1. Steppe	Chernozems	Meadow-Chernozem soils	--
		Chestnuts	Meadow-chestnut soils	--
	2. Meadow	--	--	Meadow soils
	3. Meadow-bog	--	--	Meadow-bog soils
	4. Solonetz	Solonetz steppe soils	Solonetz meadow, solodi	
	5. Solonchak	--	--	Solonchak steppe

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[a] Groups are subsequently divided into subgroups, genera, species, types and sub-types.

[b] Soil on carbonate rocks amongst brown forest soils.

Table 2 (Continued)

Soil Classes	Soil-formation groups (soil-sub-classes)	Soil groups		
		Automorphic	Automorphic-Hydromorphic	Hydromorphic
Class VI-Sub-boreal desert soils	1. Desert	Brown semi-desert soils	Brown meadow-desert soils	--
		Gray-brown	--	--
	2. Takyr	--	Takyrs	--
	3. Solonetz desert	Solonetz desert	Solonetz meadow-desert	--
	4. Solonchak desert	--	--	Solonchak desert
II. World group classes of Subtropic soil Formation				
Class VII-Subtropic humid forest soils	1. Zheltozem	Zheltozem	Gley Zheltozem	--
	2. Krasnozem	Krasnozem	Gley Krasnozem	--
	3. Bog subtropic	--	--	Bog subtropic soils
Class VIII-Subtropic dry forest Savannah and steppe soils	1. Cinnamon-brown earth	Cinnamon-brown soils	Cinnamon-brown meadow forest soils	--
		Gray cinnamon-brown soils	Gray cinnamon-meadow-steppe soils	--
	2. Sod subtropic ?[b]	--	Smolnitsy ?	--
	3. Meadow subtropic	--	--	Meadow subtropic soils
	4. Solonetz subtropic ?[c]	Solonetz subtropic ?[c]	Meadow-solonetz subtropic soils ?[c]	
Class IX-Subtropic desert soils	1. Sierozem desert	Sierozems	Meadow-Sierozem soils	--
		Subtropic desert soils	--	--
	2. Solonchak subtropic	--	--	Solonchak subtropic
III. World group classes of Tropic Soil Formation (Not as yet divided into types)				
Class X-Tropic humid Savannah and forest soils				
Class XI-Tropic dry-forest Savannah soils				
Class XII-Tropic desert soils				

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[c] Provisional Entry.

Table 3

Classification of prevailing USSR genetic soil groups
(by I. P. Gerasimov)

Sphere or kingdom of soil formation	Genetic soil group formations	Classes of Genetic Soil groups		
		Zonal	Intrazonal	Azonal
	Arctic	Arctic Tundra soils Tundra gley	Arctic Solonchaks Arctic Bog Soils	
Glacial	Permafrost soils	Bald mountain soils Pale yellow (ferrous) taiga	Dark-colored soils of the water meadows	Frozen bog soils of the tree covered marshlands
	Boreal	Podzolic Gray forest Acidic non-podzolic forest	Sod-carbonate Podzolic-bog Gray forest gley	Bog Meadow-bog
Boreal	Humid	Sod (mountain meadow) Brown forest Chernozems Chestnuts	Brown forest gley Sod gley Meadow-Chernozems Meadow-chestnuts	Solodi Solonetz Solonchak Takyr
	Arid	Brown desert steppe Gray-brown desert	Brown meadow steppe Takyr	--
	Dry (arid)	Cinnamon-brown Gray cinnamon-brown	Meadow cinnamon-brown Meadow Sierozem	Bog soils of the subtropic bogs
Subtropic	Moist (Humid)	Sierozems Zheltozem Krasnozem	Zheltozem gley Krasnozem gley	

to retain the concept of "soil species" for specifying the stage of genetic development of the soil (for example, the weakly, moderately, and strongly podzolic soils; the weakly and moderately humic, and rich chernozems, etc.). The different textures of the soils constitutes the basis for separating the types, while the most important characteristics of their petrographic composition, conditioned by the composition of the soil-forming parent material are used in establishing the soil subtypes.

Thus, we can say that the most important genetic soil properties being formed in the course of soil formation have been mainly covered by the first group of taxonomic subdivisions, used in Soviet Soil Science (the genetic soil group, subgroup, genus species), whereas the lithologic characteristics basically inherited by the soil from the parent material are indicated in the second group of taxonomic units (type, sub-type). We should, however, point out the fact that this, of course, does not deprive these properties of an important genetic and agronomic meaning nor obviate the need of carefully taking them into consideration when classifying soils.

Our review of the scientific principles of the Russian school of thought would be incomplete if we did not consider the question of taxonomic units in soil classification higher than the genetic soil group. We must point out that Russian soil scientists, beginning with Dokuchayev, have always been concerned with the principles of the association or classification of genetic soil groups. For example, Dokuchayev and Sibirtsev have divided all genetic soil groups known to them into three great groups -- the zonal, intrazonal. and azonal, interpreting the first of these groups on a purely geographic plane as group of soils characteristic of certain natural geographic zones -- the tundra, taiga, steppe, semidesert, etc. (Table 1). A similar geographic method of grouping genetic groups originated by Dokuchayev continued to develop in Soviet soil science. This method was presented in the well-known report of Afanas'yev (1) in 1927 at the First International Congress of Soil Scientists in Washington, and in the reports of Ivanova (27), Rozov (43) and Volobuyev (5)[1] in 1956 at the 6th International Congress of Soil Science in Paris.

Without examining the merits of the latest classification schemes of soil groups set forth in these reports, we see that 1) the biological factor in soil formation occupies a particularly important position (the characteristics of the biological cycle of substances within the various types of plant cover-tundra, forest, sod, steppe, etc.); 2) there exists the tendency to associate all the principal characteristics of the processes of soil formation (the rate of transformation and translocation of substances within the various soil groups, weathering process, etc.) with the general geographic belts and zones (for example, in the world soil groups and classes). We see in Table 3 a similar geographic classification of the prevailing genetic soil groups in the USSR, as worked out by I. P. Gerasimov.

Geographic groupings of genetic soil groups are impressive, for, by reflecting concrete natural patterns, they attempt to strengthen the close associations which exist between soil groups and the general conditions of soil formation. However, similar schemes have not sufficiently indicated the genetic nature of these associations. And so, there have been and continue to be other trends in resolving the classification question in Russian (Soviet) soil science.

The tendency to group genetic soil groups by the predominant role (within the processes of soil formation) of some factor, the soil-former (the so-called climatogenic, phytogenic, halogenic, hydrogenic series of S. A. Zakharov or similar series by D. G. Vilenskiy) has already been observed for a long time in the works of Glinka (16), Zakharov (24) and Vilenskiy (2, 3). However, this trend of thought on soil classification questions has not been substantially developed or practically applied in the USSR.

Studies by Kossovich (30), Glinka (17) and Gedroits (6) on the physicochemical nature of the processes of soil formation have considerably influenced the development of scientific ideas on soil classification. As we know, K. K. Gedroits, who has conducted profound research on the physicochemical phenomena in soil colloids, has suggested as the basis for a general classification of the soil processes, the properties of the adsorption complex and the composition of the exchangeable cations in the various soil groups. In his own famous scheme Neustruyev (35) attempted to apply Gedroits' idea for constructing a broad classification scheme. However, it has been proven that the variety of natural processes in the natural soils was so great and, at the same time, so specific for the separate soil groups, that it could not be completely covered or fully explained by Gedroits' concepts. This is quite obvious from the scheme of Neustruyev, who shows the complex combination of mutually different, simple soil phenomena (of podzolic, sod, solonetz, and other soils) within the various genetic soil groups. Nevertheless, we cannot fail to see that the general trend of scientific thought, based on the works of Gedroits and other soil scientists and leading to the discovery of the physical and chemical nature of the soil formation processes in the various genetic soil groups, will be, henceforth, of vast importance in resolving soil classification questions.

Especially important in developing the general theory of soil classification was the advancement of the historic-evolutionary principle set forth in the proceedings of the All-Union Soil Conference of 1932 (28, 38) as well as in Vil'yams' views (4) on the development of soils and the soil-forming process in close association with and mutual dependence upon the evolution of the whole organic world (beginning with the plant cover). As Gerasimov (10) has pointed out, the historical interrelationships among genetic soil groups shall overstep the bounds of soil science when the evolutionary problem has been scientifically formulated in soil science and shall pass into the problem of the geological development and evolution of the entire biosphere, as a whole, as well as into the problem of the components forming the biosphere. At the same time, questions of genesis, evolution, and geography of some soil groups shall enter the field of historical formation of a corresponding natural geographic landscape with which this soil group is organically associated (for example, the coniferous taiga of Siberia, the mountain-meadows of the Caucasus, the steppes of the Ukraine, etc.).

Such a broad concept of the historic-evolutionary questions on soil classification, as it applies to units on a high taxonomic level, has been confined, for the present, to only a general statement, since we are not as yet in a position to use the new scientific ideas in a concrete classification structure. This is the problem for future research. Yet, we must point out that, from the standpoint of principle, only the strictly historical (evolutionary) concept in the classification problem of soil science can organically unite the geographic and genetic approaches described previously.

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[1] The classification scheme by I. P. Gerasimov, A. A. Zavalishin and Ye. N. Ivanova (14) was worked out on the basis of these ideas, but a large part of the classification was assigned to the moisture series.

Such, in brief, are the latest scientific ideas of Soviet soil science on the general theory of soil classification.

We shall now turn to the Western European scientific trend in soil classification, which is also widespread. This trend is older than the Russian (i. e., the Dokuchayevian school) with sources going back to pre-Dokuchayevian agro-geological and chemico-agricultural views on soils. This is evident, for example, from the fact that the physical (by texture supplemented by humus and lime) classification of soils by A. Thaer (70), the petrographic by Fallon (47), the chemical by Knop (52), and the geological classification (by the degree of weathering of the rocks by Richthofen (61) and others, are the most well-known old classifications of this trend.

Dokuchayev's scientific ideas (in the light of which soils had been finally separated from parent materials and subjected to a separate genetic subdivision) have had a different effect on Western European soil scientists of recent years. Several of them have taken up entirely new scientific positions, which have almost no connection with the old views. We cite as an example the soil classifications of Ramann (59, 60), who strove to introduce into the old views Dokuchayev's concept of "genetic soil group" (as a basic classification unit) applying them to the soils of subtropic and tropic lands. It is interesting to note in this regard that Ramann was the first to set up a new and important separate genetic group of brown forest soils. However, parallel with a complete creative assimilation of Dokuchayev's scientific ideas on soil classification, we find other examples among recent Western European works. For example, let us take the well-known soil classifications by Sigmond (63, 64), who has worked out a detailed system of taxonomic units (categories) of 8 subdivisions (basic groups, subgroups, orders, basic types, subtypes, local variants, physical and physiological soil classes). There does not exist a complete genetic character in any one of these subdivisions, much less in a combination of them all. However, let us consider the most common section in Sigmond's classification, which covers the three highest categories (basic groups, subgroups, and soil orders, (Table 4). As seen from the corresponding terminology, all subdivisions of this scheme are the result not of a complete complex of the most important and mutually dependent soil properties associated with their origin (i. e., a specific combination of soil-formation conditions) but are based merely on individual characteristics of the petrographic or chemical composition of the soil mass treated separately, to which is attributed a different taxonomic value. Thus, for example, the basic groups of soils have been divided according to the predominance of the organic or mineral components in the composition of the soil mass while the soil subgroups have been divided according to the degree of decomposition of the organic substances and weathering of the mineral substances, and the orders, etc., according to the different chemical, physicochemical, or mineralogic characteristics of the soil mass.

We should realize, then, that although we find in Sigmond's classification several genetic subdivisions (mainly in the "category" of basic types) they do not determine the general principles of this classification. We consider the soils in Sigmond's system basically as the organic mineral masses of a diverse petrographic composition and they are classified according to the individual chemical properties which are being considered without properly associating these properties genetically with one another, and with a complex of soil formation factors.

Recent tendencies in resolving soil classification questions by Western European researchers can be described as a tendency towards synthesizing the genetic and agro-geological trends. As an example of such research work, we shall point to the soil classifications by Stremme (66, 69) and Kubiena (53, 54).

In his works on the classification and cartography of the soils of Germany, Stremme has extensively applied Dokuchayev's ideas on soil formation factors, attempting to combine his approach with the mineralogic-petrographic approach to soils. In this connection, Stremme considered climate and time (as "invisible," "indirectly affecting," etc., factors) least important among Dokuchayev's soil formers, and placed primary emphasis on parent materials, vegetation, water and topography. In accordance with such a theoretical view, Stremme introduced four groups of soils in his classifications in the form of systematic subdivisions of the highest order: the vegetative (biogenic), the humid (hydrogenic), the rocky (lithogenic) and the mountain soils (orogenic).[2] Such a division enables Stremme

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[2] Without discussing these concepts in detail, we will only note here that as already mentioned, similar proposals in Russian soil science had been made in his time, but had not been widely accepted.

Table 4

Classification scheme of soils
(by Sigmond (64))

I. Main Groups	II. Subgroups	III. Soil Orders
1. Organic Soils	1. Raw organic soils (turf)	1. Turfs, poor in bases 2. Turfs, rich in bases but not salty 3. Salty turfs
	2. Humified organic soils (bog)	4. Acid peat soils 5. Neutral peat soils 6. Salty peat soils
2. Organic Mineral Soils	3. Raw organic mineral soils	7. Endodynamic soils 8. Ektodynamic soils 9. Pseudodynamic soils
	4. Humic siallites	10. Hydrogen soils 11. Calcium soils 12. Sodium soils
	5. Ferric siallites	13. Brown earth 14. Red earth 15. Yellow earth
	6. Allites	16. Pure allites 17. Siallitic allites 18. Bauxitic allites
3. Purely Mineral Soils	7. Raw mineral soils	19. Soils of mixed rock debris 20. Soils of mineral grits 21. Soils of fine mineral silt
	8. Mineral soils with average decomposition	22. The calcium of the mineral matter partly mobilized 23. The silica of the mineral matter partly mobilized
	9. Mineral soils with the end-products of decomposition	24. Soils with easily soluble salt crust 25. Soils with slowly soluble salt crust

to focus attention in his classification upon the degree and nature of composition changes of the parent material caused by the process of soil formation. It is only in the finer subdivisions that he uses the term "genetic soil group," attaching his own meaning to the term. We can see this from the legend of the latest soil map of the German Democratic Republic, prepared by Stremme (69), where the genetic soil groups have often been divided on the basis of the difference in the material composition of soils.[3]

Another example of recent Western European studies in soil classification is the work of the soil scientist Kubiena (53, 54). Owing to the broad scope of subject matter and use of new methods in soil study, his works on general theoretical problems in soil science have achieved widespread fame.

Kubiena calls his own classifications a scheme of the natural systems of soils or a natural soil system, consisting of 7-8 taxonomic units (kingdoms, families, groups, or divisions, classes, subclasses or orders, types, subtypes, varieties, and subvarities) for which he constructed intricate tables with separate indices and numbers for the individual subdivisions.

We shall cite Kubiena's general scheme of 1948 (23) (Table 5), but we shall also use the more detailed table,[4] published in 1954 (54).

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[3] These soils are the black and brown steppe, forest-steppe, humid forest, mineral and organic humid, dark and light carbonate soils, on mottled parent materials, etc.

[4] This scheme has been published in Pochvovedeniye 1956, No. 11 (reviewed by K. V. Krumin'sh).

Table 5

Natural Soil System
(by V. Kubiena (58))

A. Hydro-semi-terrestrial Family		B. Terrestrial Family
a) Group of submerged soils	b) Group of semi-terrestrial soils	Group of terrestrial soils
Type 1. Submerged humic Type 2. Dy Type 3. Dygyttja Type 4. Gyttja Type 5. Sapropel	1. Gley non-humic soil II. Semi-terrestrial class of gyttja 1. Order: coastal soils (Küstenböden) Type 1. Tide-land swamp soils (Wattböden) Type 2. Marsh soil (Marschböden) 2. Order: semi-terrestrial gyttja Type 1. Swamp soil (Sumpfboden) Type 2. Marsh soil (Anmoore) III. Peat class (Moorböden) Type 1. Lowland moor Type 2. Transitional moor Type 3. Upland moor Type 4. Peat-tundra IV. Saline class (Salzböden) Type 1. Solonchak Type 2. Solonetz Type 3. Solodi	I. Raw soil class II. Ranker-like soil class Type 1. Tundra (non-gleyed) Type 2. Rankers III. Rendzina class Redzina type IV. Steppe class Type 1. Sierozem Type 2. Light brown semidesert Type 3. Chestnut Type 4. Chernozem V. Brown and red loams class 1. Carbonate clay order Type 1. Brown carbonate (Terra fusca) Type 2. Red carbonate (Terra rossa) 2. Order: brown and red loam on silicate parent material Type 1. Brown loam Type 2. Red loam VI. Red Earth and Laterite class Type 1. Carbonate red earth (earthy Terra rossa) Type 2. Tropic and sub-tropic on silicate parent material. Type 3. Laterite VII. Brown earth class Brown earth type VIII. Podzol class Podzol type

Both schemes include three families (the soil formation groups): the submerged or underwater soils, the semiterrestrial soils (submerged or ground water soils) and terrestrial (dry land) soils. The first of these families includes formations (lacustrine deposits) which usually do not apply to soils, but which are on a level with the lowland moors. A second family (group) includes various soil classes -- the primitive, peat, and salinized soils. Finally, the third family of terrestrial soils onsists of the most varied soil formations -- from the Arctic and alpine soils, forest and steppe soils of the temperate zone, to the lateritic soils of the tropics and subropics.

Kubiena's classification scheme is of great interest, expressing very fine and detailed observations of the properties of several soil formations in Western European countries, observed by many European soil scientists, and, above all, by Kubiena himself. These include observations of the genesis of rendzina soils (for example, the mull and mull-like rendzinas), the brown forest soils (the eutrophic and oligotrophic brown soils), the gley soils, etc. We can also clearly see in this scheme the author's desire to establish a theoretical generalization of similar scientific observations. Thus, for example, as a basis for preparing a list of submerged (underwater) soils he has obviously taken the concept of transition from underwater formations (Gyttja and Sapropel) to above-water formations (bog), while for the semi-terrestrial soils he has used the idea of transition from the peat-swamp soils through the salinized soils to the dark or mottled colored soils of the flood plains. Finally, for the family of terrestrial soils this idea has been apparently expressed as the gradual development of the soil profile from the system of AC horizons to the system of ABC horizons (from steppe soils to forest soils).

Kubiena's desire to include as many observations of the various soil properties as possible in his general soil classification explains the complex nature of his scheme, while a somewhat abstract concept of the predetermined genesis of soils prevented attributing to the soil a simple and clear inner logic. Yet, in many elements of this system we can see a considerable similarity in the scientific approach to soil classification to the methods used by Soviet soil scientists (for example, in dividing many of the soil groups) along with basic differences (for example, in evaluating the role of the biological factors).

Thus, we should see from what has been said, that the development of recent Western European scientific concepts in soil classification has pursued a somewhat peculiar course. The desire to synthesize creatively the soil-mineralogic approach to soil systematics with the scientific ideas and principles of Dokuchayev's genetic soil science constitutes the main feature of this development in scientific thought. At the same time, the desire to consider as fully as possible the mineral and petrographic characteristics of soil formations in classifying soils, even when they have been entirely inherited by the soil from parent materials, is obviously the most important manifestation of the old classical traditions in Western European soil science. At the same time, in the recent works of Western European researchers the tendency to apply creatively the ideas of the Dokuchayevian trend for studying in detail the soils under unique Central European conditions can be seen.

As a result of the considerable difficulties created by this complex course, much in the present day scientific works of Western European scientists seems controversial to us. However, we do not doubt that as 1) the scientific study of this problem, 2) the practical examination of the results, and 3) the continually closer mutual comparison of the scientific schools continue, the progressive elements in Western European studies on soil classification will steadily increase, while the obsolete elements will disappear.

We shall now examine the American scientific trend in soil classification. This trend is considerably younger than the Western European school of thought. Until Marbut's works (57, 58, 59), i. e., up until the 1920's, soil research in the United States pursued a purely empirical approach to soil classifications, based on the experience of the local population and the productive capacity of agriculture. However, we should not fail to note that there exists in several old American studies on soil science a totally independent development of the elements of the genetic scientific approach to soils. This applies mostly to the works of Hilgard (36, 48, 49),[5] Whitney (36, 73), and Coffey (46). It is also important to note that it was at this time that the concept "soil series" (based principally on soil texture) was first used in research work in American soil science. Of greatest importance in the subsequent development of the American trend in soil classification were the studies of Marbut, the greatest soil scientist of the United States. As we know, he had profoundly studied the scientific ideas of Dokuchayev's soil science and creatively applied these ideas in his own study of the soils of the North American continent. He considered that soil classification should be genetic and should be the result of a complex of their most important properties. From this point of view, Marbut also criticized several Russian studies for their unwarranted emphasis on soil formation factors (especially climate) at the expense of the actual soil characteristics.

Marbut presented his first, more or less fully worked out, general soil classification at the First International Congress of Soil Science in 1927 (55, 56). He used seven taxofomic categories in this classification of which the second category (soil series) and fourth and fifth (great soil groups) are particularly important. The great soil groups, in Marbut's taxonomic units correspond, on the whole, to the concept of "the genetic soil group" in Russian (Dokuchayevian) soil science or to certain groups of such types. This is the result of the general principles involved in dividing these soil categories (the geographic-genetic soils, by association of the properties) and the specific list of "great soil groups." Marbut included many Russian soil groups (the podzols, the brown forest soils, the chernozems, the chestnut soils, the brown soils, the sierozems) together with "miscellaneous" large soil formations not as yet broken down (the northern temperate pedocals, the southern temperate pedocals, the red and yellow soils, the prairie soils, etc.). The "soil series" concept in all of Marbut's classifications has not been fully revealed.

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[5] Whitney founded the Soil Bureau in the Department of Agriculture in 1894 and initiated systematic soil studies in the United States of America.

From the explanatory notes to the 1927 classification scheme (56), when dividing the soil series we should only consider the local geographic characteristics and texture together with the genetic features. There have obviously been included in this important classification category those empirical local soil subdivisions which American soil scientists have extensively used in soil field studies.

It is of interest to note that along with Marbut's scheme, another general American soil classification by Shaw (62) was presented at the First International Congress of Soil Science. This scheme was of an agricultural-geological character and constructed almost entirely according to individual soil properties -- their reaction and texture, petrographic composition of rocks, stage of detritus, color, etc. The lowest taxonomic orders, i. e., the soil series, were the only common category in Marbut's and Shaw's classifications.

Marbut worked on a general classification of soils over a period of years and presented his results in 1935 (57) in the form of a new classification concept (Table 6) which was worked out in greater detail than the earlier scheme. After having kept some of the basic categories (taxonomic units), Marbut's classification added more detailed lists of the zonal and intrazonal great soil groups. Most of these subdivisions correspond to Russian genetic soil types. However, the "soil series" which directly incorporates the "soil units or types" exists at the lower taxonomic level and in Marbut's new classification.

Following Marbut's death, the official leadership in American soil research passed to Kellogg (50, 51), who published a general soil classification scheme (for the highest taxonomic units above "the great soil group") which corresponding factually to Marbut's scheme, more conclusively emphasized the geographic-genetic principles which had been used to construct it. We can see the same tendency existing in the general soil classification scheme of Baldwin, Kellogg, and Throp (45) (Table 7). The structure of the "great soil groups" has been more precisely defined here and is almost the same as the list of Russian genetic soil groups (except for the subtropic and tropic soils which are little known to Soviet soil scientists). In addition, the general geographic characteristics (more precisely the groupings) of soil groups which, on the whole, correspond to the latest tendencies in Soviet soil science (See Tables 2 and 3) have been substantially more accurately defined in the higher taxonomic units (suborders and orders).

However, there was a great difference in views between this soil classification scheme and the Soviet system as far as the fine taxonomic subdivisions were concerned. We will consider these subdivisions insofar as this classification scheme has been published without any changes in principle by Thorp and Smith (72), as part of a special collection of the U. S. Department of Agriculture whose object it was to "set forth the theoretical principles of the American system of soil classification."

In 1950, Gerasimov (15) published in this collection a detailed review dedicated chiefly to the fine taxonomic subdivisions of the American soil classification scheme. Another review (13) was published in 1956 on the same subject based on a criticism of the soil chapter in the collection "American Geography." We will confine ourselves only to general remarks regarding these reviews.[6]

We find in the American system of soil classification a clearly expressed dualism in the approaches to the definition of the nature of the highest (great soil groups) and lowest (soil series) taxonomic orders. In the first case, the geographic-genetic approach which is in principle the same as the approach of Soviet soil scientists, is predominant in American Science. In the second case the empirical method is basically applied. This consists of a division of the very fine soil subdivisions (series) designated by local geographic names and by only the soil texture or the character of the parent material. As a result, the American system of soil classification prevents us from defining the concrete genetic characteristics of one or another soil series, and, consequently from comparing them with each other and incorporating them into higher homogeneous groups, etc. Moreover, the actual principles involved in dividing the soil series are confusing. We should point out that American soil scientists themselves have recognized this important drawback. Thus, for example, in the article by Moon, Ligona and Henderson (58) in the same collection, mention is made of the fact that "in conducting soil field studies the scientists have shown the tendency to interpret and apply Marbut's criteria in soil series in a too literal and narrow sense. Several soil field studies have been made based on the assumption that each characteristic (for example, the structure, color, texture, etc.), indicated in Marbut's criteria can be used as a basis for dividing the soil series. "Field mapping would suffer very much" these authors conclude "if research were based on such a principle."

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[6] At the Sixth International Congress of Soil Science in Paris, the American representatives did not present their reports on general classification problems. However, the head of the American delegation, Kellogg, submitted to the Soviet delegation for study a separate treatise entitled "Outline of a Scheme of Soil Classification" published under manuscript rights. As a result, we are not discussing this work in this article.

Table 6

Marbut's scheme of soil classification (57)

Category VI	Pedalfers (VI-1)	Pedocals (VI-2)
Category V	Soils from mechanically comminuted materials Soils from siallitic decomposition products Soils from allitic decomposition products	Soils from mechanically comminuted materials
Category IV	Tundra Podzols Gray-brown podzolic soils Red soils Yellow soils Prairie soils Lateritic soils Laterites	Chernozems Dark-Brown soils Brown soils Gray soils Pedocalic soils of Arctic and Tropical regions
Category III	Groups of mature but related soil series Swamp soils Gley soils Rendzinas Alluvial soils Immature soils on slopes Salty soils Alkali soils Peat soils	Groups of mature but related soil series Swamp soils Gley soils Redzinas Alluvial soils Immature soils on slopes Salty soils Alkali soils Peat soils
Category II	Soil series	Soil series
Category I	Soil units, or types	Soil units, or types

With regard to principle, those scientific and practical motives by which we had to consider carefully (in soil classification) the local characteristics of the soils and the nature of the parent material seem clear to us. We may also mention that in prerevolutionary Russian soil science this phase of soil classifications -- by virtue of specific historical causes -- has been only slightly worked out and not sufficiently taken into account. Emphasis was then placed on the higher categories of soil classifications, wherein not the individual and local soil characteristics but the more general genetic features, in particular, the bioclimatic-soil character, had been stressed. Therefore, it is probable that Russian research of that period had attained great fame, by its "especially theoretical" ("climatic") studies. However, as we have already seen the situation suddenly changed in the Soviet period because of the close association and contact with the demands of Socialist agriculture; in both the theoretical and practical soil studies attention has been directed to the classificational division of soil groups (into subgroups, genera, soil species, types and sub-types) for considering the local soil characteristics and nature of the soil-forming rocks. This was all done on a systematic geographic-genetic (Dokuchayevian) scientific basis.

In this respect, the history of the development of the American system of soil classification was, obviously, different. The term "soil series" had been introduced into soil research practices in America before corrobating the all-round genetic approach to soils. And although this term had undoubtedly changed its meaning substantially (from that time), its empirical nature has been considerably retained even to the present day. These are probably the historical roots of that dualism in methods found in American soil classifications which had been observed earlier. This dualism, it seems, is not a strong argument in behalf of the American system; it not only does not heighten but makes more difficult the possibility of scientific mutual understanding and exchange of the scientific achievements

Table 7

Soil classification scheme of M. Baldwin, C. Kellogg, J. Thorp (45)

Category VI	Category V	Category IV
Order	Suborder	Great Soil Groups
Zonal Soils Pedocals	1. Soils of the cold zone	Tundra soils
	2. Light-colored soils of arid regions	Desert soils Red desert soils Sierozem Brown soils Reddish brown soils
	3. Dark-colored soils of semi-arid, subhumid, and humid grasslands	Chestnut soils Reddish Chestnut soils Chernozem soils Prairie soils Reddish Prairie soils
Pedalfers	4. Soils of the forest-grassland transition	Degraded Chernozem Non-calcic Brown or Shantung Brown soils
	5. Light-colored soils of the timbered regions	Podzol soils Brown Podzolic soils Gray-brown Podzolic soils
	6. Lateritic soils of forested warm-temperate and tropical regions	Yellow Podzolic soils Red Podzolic soils (and Terra rossa) Yellowish-brown Lateritic soils Reddish-brown Lateritic soils Laterite soils
Intrazonal Soils	1. Halomorphic soils	Solonchak or Saline soils Solonetz soils Soloth soils
	2. Hydromorphic soils	Meadow soils Alpine meadow soils Bog soils Half-bog soils Planosols (with compacted horizon) Ground water Podzol soils Ground water Laterite soils
	3. Calcimorphic soils	Brown forest soils Redzina soils
Azonal Soils		Lithosols Regosols (includes dry sands) Alluvial soils
Category III. -- Family[a]; II. -- Series; I. -- Types		

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[a] Families incorporate series and have no genetic relationship with the great groups.

among American, West European, and Soviet (Russian) trends in soil classification. And this is precisely the chief international problem. To destroy this barrier completely would be of great value to the soil scientists of various countries as well as to the entire field of international soil science. Not only would it be more productive to exchange data and the results of studies in research and methods but by destroying this barrier, it would become easier to coordinate the separate principles of soil classification by combining the greatest achievements of the various scientific trends in soil science. And if this article, aimed at an objective comparison of the different theoretical approaches to soil science, somewhat facilitates mutual understanding, we shall then consider our efforts justified.

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A CLASSIFICATION SCHEME FOR DELTA SOILS OF THE ARID REGIONS OF THE USSR[1]

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A classification of delta soils becomes particularly important when we consider their extensive use in agriculture. The youth of most delta surfaces, and the stratification of soil forming layers considerably limit the possibilities of investigating soil by the classic methods of genetic soil science (analysis of the formation of the soil profile, and the use of data of the total chemical analysis, texture, exchangeable cations, etc., create difficulties). These difficulties continue to exist at present but do not lessen interest in the study of delta soils (1, 8, 11, 16, 17, 18, 19, 22, 23, 24, 25, etc.). Owing to this interest, we can justify making generalizations and setting up a classification scheme for delta soils. The first general soil formation scheme for deltas of different soil zones appeared in 1946 (16).

A classification scheme of delta soils presupposes the solution of a very vital problem, i. e., whether we can consider the most prevalent soil groups in the deltas as typical, in accordance with the views of V. V. Dokuchayev, N. M. Sibirtsev and L. I. Prasolov, which are being developed by Gerasimov (7), Ivanova (12), Rozanov (26), Rozov (27), and others.

We know that everything typical in the field of natural science develops through a continuous evolution process. If we adhere to the principles of Prasolov, we must supplement the concept of typical soils with that of their widespread occurrence in the area of the materials. Under delta soil formation conditions this occurrence may be replaced by the concept of reproducing typical characteristics in the soils as soon as the necessary prerequisites have been created for this concept (at a different time and at different places).

In the problems of the genesis and classification of soils, Dokuchayev's soil science employs considerably the principle of the conformity of soils with environment. In noting this relationship, I. P. Gerasimov wrote, "Each genetic soil group, as a direct result of Dokuchayev's basic principles of soil science, is formed under the influence of a specific combination of soil formation factors, i. e., the group corresponds to a specific complex of natural conditions" (7, page 63). N. N. Rozov (27), Ye. N. Ivanova (12) and many others have expressed similar views.

A thorough study of soil interaction with environment is one of the ways of becoming acquainted with and differentiating soils, because bodies and natural phenomena are known to interact. If we find that the interaction of the various soils is essentially different, we cannot incorporate them into related groups, i. e., subdivisions, which have been divided on the basis of the same origin, transformation and translocation (migration) processes of matter as formulated by L. I. Prasolov,[2] as well as on the basis of a similar character of moisture and thermal relations (Table 1), ecological conditions, vegetation types, and productivity levels (12).

In the delta regions, where a large variation in water relations, ecological conditions and plant associations are observed, it is apparent that several soil groups can be formed. However, these possibilities may not develop immediately because of the time factor.

In this connection we should be concerned with the problem of the so-called "ontogeny" of the concrete soils and "phylogeny" of the soil groups (from Gerasimov, 7), both of which have been little treated in the soil science field.

Delta soils are generally formed by the

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[1] Presented at the First All-Union Delegates Conference of Soil Scientists in 1958.

[2] A quote from the work of I. P. Gerasimov (Pochvovedeniye No. 8, 1954).

Table 1

A Classification Scheme for Delta Soils of the Aralo-Kaspiyskaya Lowlands

Stage	Group	Suborder	Soil sequence		
			River Beds	Flood Plains	Swampy Depressions
I. Submerged soil formation	1. Submerged soils	1) Mineral accumulative 2) Biogenic accumulative (a conditional separation)			
II. Excessive moisture (constant) soil formation	2. Bog soils (delta)	1) Clay-bog	Little developed in the estuary region (accumulation of new alluvial deposits is predominant)	Boggy. Water-meadow (transitional)	Boggy, gleyed. Secondarily swamped, nonsalinized, and desalinized
III. Meadow soil formation	3. Meadow soils (delta)-by zones	1) Stratified undeveloped 2) Meadow, flood-plain 3) Meadow sod including non-irrigated, irrigated (in the cultivation) 4) Meadow-solonchak[a]	Meadow, flood-plain (forest) Meadow, little humus (light)	Meadow turf	Meadow, dark-colored with temporary excessive moisture (liman and bog)
	4. Solonchak	1) Meadow-solonchak 2) Solonchak and meadow-mineral (in brine) 3) Coastal solonchak 4) Secondary solonchak 5) Solonetz-solonchak with high ground waters		Not subdivided into sequence	
IV. Transition stage from meadow to steppe or to desert soil formation	5. Meadow-steppe soils (subdivided by zones)	1) Meadow-steppe 2) Meadow-steppe solonchak			
	6. Solonetz	1) Takyr-like sol. 2) Solonetz			
	7. Meadow-desert soils (transition to gray-brown)	1) Desert, former meadow and bog 2) Slightly developed gray-brown			
	8. Takyr soils	1) Takyr-like 2) Takyr 3) Takyr in trans. stage to gray-brn.			
	9. Residual solonchak	1) Residual solonchak 2) Solonchak paragenetically associated with takyrs			
Anthropogenic stage (without direct association with preceding stages)	Irrigated cultivated soils (especially subdivided should be the "Rice-like" soils)	Not subdivided			

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[a] May be subdivided into sequence partly in the same way as meadow soils. Besides, on river bed surfaces the soils have a relatively greater chloride composition of salt, than in the flood-plain and swampy depression sequence.

Delta soils are generally formed by the interaction of established factors. Young, slightly developed delta soil, naturally, cannot change the state of the geographic environment in conformity with characteristics of the initial stage of its development. On the other hand, a rapid development of the basic properties of that soil group which corresponds historically to the given conditions takes place during the combined action of environmental factors. It is only later on, by taking part in the general development characteristics of the natural complex of conditions, that the soil formed is capable of affecting the nature of this development.

Of all the factors in delta soil formation, water relations are of particular importance. In conformity with the character of these relations the initial stages of soil formation apply to the hydromorphic series. Specific plant associations correspond to this series. Sharp differences in the water relations and plant composition of the various delta soils may be, although indirectly, a generally reliable criterion for relating soils to different groups.

We know that only certain ecologically close combinations of soils are formed in the majority of deltas of arid regions and are regularly replaced by vegetation. This is the result of a definite, historically established conformity between the different elements in the natural complex during a repetition (typical nature) of the environmental conditions. In this regard, the soils should be considered as typical. With nontypical formations the regularly recurring combinations are impossible. Reproduction of these combinations is regarded, in classification terms, as a characteristic equivalent to the widespread occurrence of soils in the area of the subsoils.

These explicit views enable us to see as predominant delta soils the definite historically established typical forms produced by their own "phylogenesis." In each separate case we can point to a different expression in typical qualities, properties and characteristics of the concrete soils.

The principal groups of delta soils cannot help but have an effect on the general climatic conditions in the regions of their formation. At the same time, the absence of a previous history apart from the one which corresponds to delta conditions is common to these groups. The biological and geological cycles of matter under delta conditions at definite stages attain a well-defined direction. Although their results will remain heterodynamic in this case, the soil formation conditions are very distinctive.

All delta soils begin to be formed, as mentioned previously, under moisture conditions. In accordance with the development of the delta landscapes, this moisture state is replaced later by a capillary type of moistening with which is associated the emergence of the meadow forms of soil formation. In succeeding stages, in connection with the drying of the surface and the lowering of ground water level, the root-containing layers break off from the capillary fringe. The soil is in the condition of so-called automorphic relations. Such stage of development is a specific characteristic of the deltas of arid zones. Therefore, delta soils may be divided into a special alluvial-delta series within each bioclimatic province or subzone.

We must consider the problem of evolution cycles in establishing a genetic classification of soils. Rozanov (26) has expressed interesting views on this subject. Basing his opinions on the ideas of Vil'yams and Polynov, he points to several evolution cycles as if they were enclosed within one another. The first is a small cycle or a self-evolution of soils, followed by a large or, geomorphological cycle and the last, the most common, the geological cycle. Rozov (27) also employs this scheme as one of the prerequisites for a general classification. He interprets the first cycle as being strictly biological, the second, biogeomorphological and the third as bioclimatic. From Rozov's interpretation, the delta soil evolution cycle (or series) which can be somewhat conditionally called biohydrological, corresponds most likely to the biogeomorphological cycle. Within this cycle are found the basic evolution stages and evolutionary relationships or associations of delta soils.

Considering this, most soil scientists have solved the systematization and classification problems of delta soils. The first genetic classification of delta soils was set forth by L. I. Prasolov (24, 25). Subsequent work in this direction has been carried out with soils of the Amu-Dar'ya delta (2, 8, 14, 15, 29, 30, 31), the Terek delta (11), and the Volga delta (4, 16, 17, 19, 22).

Prasolov's view of the parallel convergent series in the evolution of delta soils is found particularly in the classification scheme of Vladychenskiy, who noted two parallel series which merged into one during the transitional stage to the steppe conditions of soil formation. The classification importance of these series, however, was not accurately defined.

The idea of the evolution of delta soils as a basis for their systematization is now a generally acknowledged fact and is expressed in the works of Borovskiy (3), Tazabekov (28), Kalashnikov, Kimberg, Ye. P. Kochubey and M. I. Kochubey (13), and others.

In the classification scheme of delta soils, which is being studied here as it applies to deltas of the Aralo-Kaspiyskaya lowland, the qualitatively different stages in the evolution of soil constitute the largest subdivisions. Four such stages are outlined: 1) underwater soil formation, 2) excessively wet or bog soil formation, 3) meadow soil formation, and 4) soil formation in the transition stage from meadow to zonal forms. A definite type of water and salt regime and a definite complex of plant community with ecological conditions corresponds to each of the designated stages.

At the bottom of the delta basins rich organogenic horizons similar to surface soils may be formed. Delta soils often inherit their properties.

A group of bog soil with a clay bog subgroup is prominent at the moisture stage of soil formation in the deltas of the arid zone. The peat-bog and gley-soils are not indigenous to deltas of the region under discussion where the aridity of the zone is distinctly reflected.

Delta soils of the meadow stage show a great variety, but are characterized by common features which enable us to consider the entire group as related formations. The transpiration-evaporation and a definite type of geochemical processes are inherent in all, to some degree. Within this group are found two variants of subgroups, separable, depending upon the different rate of the sod and meadow-solonchak processes in different soils.

The subgroup of developed meadow-sod soils expresses most fully the sod process in the deltas. These soils are extensively developed in the deltas of the Volga, Don and Dunay. In other deltas, they appear only under special, more favorable conditions. The influence of zonality in the intensification of the soil process in the more northern, less arid zones (18) is expressed in this certain way.

The meadow-flood plain (forest) soils are a special subgroup where the sod process finds an unique expression. Their appearance is associated with the participation in the soil formation of the vegetation of river forests with a grass cover in the lower story.

We must provide certain basis for substantiating the separation of meadow-solonchak soils. In the classification of zonal, so-called automorphic soils, the soil salinization will be identified by a generic feature (12). This is true when this quality is inherited from the parent material or from preceding evolution stages. Salinization in delta soils is a present-day process. In accordance with this, the soil processes, including the water table are different here than with soils which have not undergone salinization. For the most part, the leaching is characteristic of the non-salinized soils in the deltas while the evaporation is characteristic of the salinized soils. Only a constant combination of one or the other relations under delta conditions makes it impossible to pose the question of the existence here of varieties of a type order.

The solonchak soils associated with ground waters stand out as a separate group. They are divided into subgroups depending upon the extent of the mineral composition of the ground waters and sources of salts. In the presence of a low mineral composition of the ground waters, meadow-solonchaks stand out in contrast to solonchaks with high mineral composition of ground waters. There is much basis for separating these and other soils. A high saline content is observed only in the upper horizons of the former soils. A succession of meadow crops may grow on such soils by using the lower, less salinized layers. These soils are different and serve as land improvement objectives. Proceeding from the varieties in the sources and forms of salinization, the subgroups of coastal and secondary solonchaks are also separated.

The solonetz-solonchak soils included in the classification scheme represent very distinctive soils. They are formed in the presence of nearby (1.5-2 meters deep) concentrated ground waters. Because of a high salinity, these solutions will cease to evaporate through the soil by retaining in the soil their own capillary fringe. From the effect of rainfall a dwarf-solonetz horizon will be formed, below which the saline horizon is located, owing to the presence of capillary solutions from the ground waters.

The systematization of soils in the transitional stage from meadow to zonal groups has been the least treated in the soil science field. The soil fertility also gradually changes when there is a gradual change in moisture conditions. A similar evolutionary path is defined usually as the "steppification" of meadow soils. In this sense, the technical term "desertization" is in keeping with desert zone conditions. However, the term conveys to a lesser extent the nature of the processes of development of zonal soils from meadow soils. The concept of desertization, likewise, applies to phenomena associated with a rapid change in the water relations (table) when "a soil formation crisis" develops in its own way. This often takes the form of a "takyrization" of the meadow soils, when unfavorable changes in the water relations are supplemented by the effect of the salt factor.

Until recently the meadow-takyr soils were termed transitional formations in the deltas of the desert zone of Central Asia (N. V. Bogdanovich, N. V. Kimberg, A. F. Shelayev, A. I. Kalashnikov, I. N. Felitsiant). This description by no means exhausts the varieties of transitional forms. In conforming with the views expressed concerning the classification scheme of transitional soils, the following principal groups have been separated:

1. The meadow-steppe soils of the deltas of the steppe and semi-desert zone, including the subgroups of nonsalinized and, to various degrees, the salinized soils with their subsequent subzonal separation which is not being taken into account by the scheme.

2. The transition soils from meadow to gray-or brown to other zonal soils of the desert zone.

3. The takyr-like soils and takyrs of the desert zone, including as a subgroup, the takyr soils, passing into the zonal gray-brown soils during their transformation.

4. The solonetz-takyr-like-soils of the other zones.

A separation of the transition soils from meadow to gray-brown has to a considerable extent a specific character and is not taken into account by the scheme. We must note that a part of the rapidly desertized soils (which have not particularly passed the stages of meadow soil formation -- former bog, underwater, etc.), should not always be considered as transition soils to zonal soils. A rapid destruction of a large part of the vegetation cover under desert conditions may be instrumental in soil loss when such surfaces are subjected to sudden wind erosion.

To incorporate takyr and takyr-like soils into a single group of takyr, soil of the desert zone must be substantiated. First of all, a swift degradation of the properties of former meadow soils occurs in these and other soils. At the same time, the biological factor loses its leading role ever more and at a certain point the abiotic processes may acquire special significance. A loss by the soil of its basic property -- fertility -- is the result. This is fortunate although it demonstrates the truth of Vil'yam's tenets concerning the leading role of the biological factor in soil formation.

We should consider as the second characteristic of takyr-like and takyr soils the constant loss by wind and the erosion of the upper, most biologically active layers (10). The result is that the soil forming process of these soils takes place on the material of the lower, gradually exposed soil horizons. This is one of the reasons for the low productivity and unfavorable physical properties of the soils under consideration. On the whole, only stage differences are observed between takyr-like and takyr soils. In practice the separation of these and other soils often cannot be based on the existence of a qualitative boundary between them. Most soil scientists consider the takyr-like and takyr soils as independent groups. However, in the earlier works of I. P. Gerasimov (5, 6) these soils were incorporated into one. We have reason to return to these views. Passing the takyr stage, these soils enter the zonal stages (if they are not destroyed by desert wind erosion). Their fertility is increased.

The takyr process finds its equivalent in the semidesert and dry steppe regions. The takyr-like-crust solonetz soils emerge under the influence of those processes which have only been modified under the conditions of lesser aridity. Certain formation features binding these soils to the takyr-like soils are indigenous of them. At the same time, they are sometimes subjected to a slight water erosion. Their effective fertility may be just as low.

Separation of the residual solonchak soils into a separate group, below which the ground waters sink to a considerable depth, is a generally acknowledged fact. We must nevertheless note that these soils passively inherit a high salinization from previous stages and that this high salinization is not the result of new conditions of soil formation. The separation of certain very special solonchak soils paragenetically associated with the takyr-like soils surrounding them is an exception. They have already been described (10) so we need not dwell on them at length here.

We know that a natural course in the evolution of delta soils is altered or even transformed by the economic endeavors of the human being. Agricultural practices have an effect on the soils in many ways, which, for classification purposes, is difficult to take into account at the present time. During irrigation, the desert soils revert to conditions corresponding to the meadow stage of soil formation. At the same time, these soils gradually acquire features common to the irrigated meadow soils. Irrigating the meadow soils holds them in check at the stage of a cultural hydromorphic soil formation. The result is that conditions remain which under natural conditions permit soils with a higher productivity level to be formed.

New soils (9, 20) may be formed as a result of century-old agricultural practices. In the classification scheme these soils are divided separately into a special type of irrigated soils. It may not be correct to draw a sharp line between these soils and the natural soils. Human economic endeavor does not countermand natural laws and does not rule out the effects of soil formation factors on cultivated soils. During the formation of these soils the Homo-sapien employs the same starting material as nature (i. e., of alluvial rivers). In the classification of soils it would seem that we should find the place of origin of specific parallel lines (series) in the development of delta soils. However, the differences between similar soils in three series are variable at various stages of development and cannot be included each time within the same classification subdivisions. For example, the soils of river beds, flood plains, and flooded areas at the meadow soil formation stage differ very sharply in their different water and water-salt relations.

Water filtering from river beds is characteristic of the soils of river bed strips. Associated with these soils is a subsoil transit of solutions. The soils have a coarse texture. The characteristics mentioned are conducive to a grass-forest formation. The soils of flood plain areas have been subjected to high-water floodings of short duration. The flushing characteristics are inherent in these soils to a great extent. As a rule they are formed on clay alluvium. Under these conditions a grass formation prevails. Finally, a state of temporary excess moisture during a prolonged stagnation period of water is characteristic of the lowland soils. The meadow conditions here alternate with bog-conditions. A special series of more dark-colored but often weakly-gleyed soils are formed on the fine-textured material. They are usually separated by their relatively few favorable moisture and physical soil properties. Moisture-excess "cold" meadows of the low areas are formed on these soils.

The differences between the soils in the three sequences mentioned at the meadow soil formation stage attain in some instances subgroup significance, while in others they are less important. We cannot consider them as specific differences so long as the different relations (Table 1) are characteristic of the soils. Sometimes the need arises to introduce a classification subdivision which corresponds, relatively speaking, to a sub-subgroup.

At the steppe or desert stage the difference in the relations of the soil processes, including the water relations (Table 1), are smoothed out. The differences in the salinization of soils, their textural and mineral composition and degree of soil development acquire great importance. These differences in the parallel series turn out to be true-to-group rather than generic. At later stages of development often only the difference in texture remains.

From the foregoing it is impossible without using a sliding scale to introduce a series in the evolution of soils which coordinates the accepted classification division. In the classification reduced to a subgroup, the subdivision is made only for meadow soils where it is possible to compare a part of the soils in sequence with various subgroups. These are the most common ideas (positions) in the classification scheme proposed for delta soils in the arid regions of the USSR. It seems that future discussions of this problem will enable us to correctly decide many practical and important issues. One of these may be the critical use of experimentation in developing delta soils when it is shifted from one set of objectives to another.

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THE PHOSPHATE LEVEL OF THE SOIL

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Various methods are used to determine the amounts of so-called available phosphorus in the soil: acid extracts, isotopes, chromatography (extraction of P_2O_5 by means of an anionite) and others. These amounts which are in direct relationship to the quantity of the soil (in terms of its specific weight), represent the capacity factor.

Up to the present time much less attention has been paid to the question of the mobility of the soil's phosphates. By "mobility" is meant a quantity that does not depend on the amount of the soil (a factor of intensity). One criterion of "mobility" might be the degree of saturation of the soil with phosphate ions. Recently individual investigators have been using the concentration of P_2O_5 in water or salt extract from the soil (12) as the factor of intensity.

It must be noted that the term "mobile P_2O_5" is too vague. "Mobile P_2O_5" is too vague. "Mobile P_2O_5" might be applied to water-soluble, acid-soluble or isotope-exchange phosphate. The concept of mobile phosphates is also inadequately defined; it has not been given a definite physicochemical meaning.[1]

Another quantity of intensity, the chemical potential, which characterizes the mobility of a component in chemical processes, has been given a strict basis in chemical thermodynamics. On the basis of the concept of the chemical potential, Schofield (10, 11) has introduced the concept of the phosphate potential of the soil. According to Schofield the magnitude of the soil's phosphate potential is the sum of the chemical potentials of two ions: Ca and H_2PO_4. Expressing the potential of both ions in terms of their activity in solution, he finds the measure of the phosphate potential in the sum: $pH_2PO_4 + \frac{1}{2}pCa$, where pH_2PO_4 and pCa are the negative logarithms of the activity (effective concentration) of the H_2PO_4 and Ca ions in the solution. He recommends determining the concentration of phosphorus in 0.01 M $CaCl_2$ extract from the soil; the magnitude of pH_2PO_4 is obtained by calculation, taking account of the pH and the activity coefficient.

The paper by Aslyng (6) contains experimental data on the phosphate potential. It also provides experimental confirmation (although only for two soil samples) of Schofield's very important assertion that the magnitude of the phosphate potential is independent of the $CaCl_2$ concentration in the solution (when the concentration of CaCl is 0.01 M or less). In other words, for a given soil the sum of $pH_2PO_4 + \frac{1}{2}pCa$ is a constant quantity. Aslyng's paper gives the phosphate potentials for a number of soil samples taken from plots that had been used for long field experiments with fertilizers (at the Rothamsted Experimental Station, the Askov Experimental Station, etc.). Comparison of the magnitudes of the phosphate potentials with data on the effectiveness of the phosphorus fertilizers did not produce a high correlation. As Aslyng himself notes, a much better correlation was obtained when the total concentration of phosphorus in the 0.01 M $CaCl_2$ soil extract was used (i.e., without recalculation for the monophosphate ion).

The phosphate potential as defined by Schofield ($pH_2PO_4 + \frac{1}{2}pCa$) is directly related to the calcium-monophosphate system. This quantity may be strictly defined in relation to this system. The problem of how to proceed from the potential in the calcium monophosphate system to the phosphate potential in the soil, which also contains other phosphate systems, still remains to be solved.

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[1] In physical chemistry the term "mobility of ions," which has an entirely different meaning, is being considered. The mobility of ions is expressed by the speed of their displacement in a solution under the action of an electric field.

This article examines an analogous, but less strictly defined concept -- the "phosphate level of the soil," which is related to the soil as a whole. We pose the following basic questions:

1) the definition of the term "phosphate level of the soil" and the determination of its relationship to the concentration P_2O_5 in an equilibrium solution; 2) the changes in the phosphate level of the soil resulting from physicochemical and biological processes (the absorption of phosphorus by plants).

PREPARATION OF SOIL EXTRACTS AND DETERMINATION OF P_2O_5

Water and salt extracts of K_2SO_4 (0.03 N) were prepared using a soil-solution ratio of 1:10. The reaction time was one hour. The water extracts were filtered through a special funnel (Sigmondi) for ultrafiltration through a dense filter to obtain completely clear solutions.

The phosphorus in the extracts was determined colorimetrically by Denizh's method as modified by Levitskiy (1), using an FEK-2 electrophotocolorimeter. By using a cell with a 5 cm light-absorbing layer in the photocolorimeter, it was possible to determine the phosphorus in the solutions with sufficient accuracy when the P_2O_5 concentration was 0.06 mg/l or higher. When the concentration in the extracts was below 0.06 mg/l, the solutions were condensed under an infrared lamp at a temperature of 60-70° C.

The water extracts have the advantage over the salt solutions that the P_2O_5 concentration is higher (at least in the case of sod-podzolic soils). In addition, the water extracts may be condensed without danger of increasing the salt concentration above the limit at which it may negatively affect color development in the determination of P_2O_5. The 0.03 N extract of K_2SO_4 may be condensed no more than two or two and a half times. Its advantage, however, is that it permits obtaining clear filtrates by ordinary filtration methods.

Soil Samples

Samples of sod-podzolic soils were taken from the plow layer (Table 1). These were differentiated according to their textures and degree of cultivation; in assigning the soils to one group or another in regard to the degree of cultivation, the following factors were considered: a) data from the analysis (contents of acid-soluble and water-soluble P_2O_5 and soil acidity); b) history of the plot; c) yield under field conditions.

CONCENTRATION OF P_2O_5 IN THE EQUILIBRIUM SOLUTION AS AN INDEX OF THE PHOSPHATE LEVEL OF THE SOIL

The concept of a "level" may be applied to a number of physical and physicochemical phenomena. It was used by N. P. Karpinskiy, (2) in his study of the soil acidity -- the acidity level.

The "difference between the levels" of two bodies characterizes the deviation from the condition of equilibrium between them. Quantities of intensity -- temperature, pressure, electrical or chemical potential -- may serve to indicate the level of some conditions characterizing these bodies. The difference between the temperatures indicates the direction in which the heat is moving. The spontaneous movement of heat will continue until equality of the heat levels -- i. e., completely equal temperatures, has been attained. In chemical processes the difference in levels is a difference in chemical potentials; this determines in which direction the mass of the substance will move, particularly the direction of movement of the mass of a component from one phase into another in the reaction.

From these remarks one may understand the concept of the "phosphate level of the soil." If two soils react with each other (in solution) the movement of phosphate ions will be from the soil with the higher phosphate level to that with the lower phosphate level. The soils are equalized when equilibrium between the phosphate levels is reached. This statement will be taken as a basic assumption not requiring proof.

From the foregoing definition, it follows that the phosphate level of a soil characterizes the general mobility of the phosphates in the soil.

Interaction Between the Soil and the Solution

In treating a weighed soil sample with phosphate solutions containing various concentrations of P_2O_5, it is possible with some degree of accuracy to select a concentration that will not change in the reaction with the soil. This will be the critical equilibrium concentration, according to Demolon (7); it might also be called the isophosphate concentration. When the P_2O_5 concentration is lower than the "critical concentration," phosphate ions move from the soil into the solution; when the concentration is higher than the "critical," there is an adsorption of phosphate ions by the soil and a lowering of the P_2O_5 concentration in the solution toward the "critical" level (7).

The following experiment will provide a more concrete example of these principles:

Table 1

Characteristics of the soil samples (sod-podzolic soils)

Location	Sample No.	Texture	Degree of cultivation	pH in 1 N KCl extract	P_2O_5 (by Kirsanov's method), mg/100 g of soil
Central experimental station of the All-Union Institute of Fertilization and Agricultural Soil Science (TsOS, VIUA), Barybino station of the Donbass RR, 60 km south of Moscow	551	silty-clay loam	high	5. 6	28. 0
	561		"	5. 5	20. 0
	562		medium	4. 8	3. 0
	144[a]		high	5. 4	17. 8
	143		medium	4. 2	8. 4
	142		"	4. 0	3. 7
	141		"	4. 4	3. 7
Former Mikhnevskiy Base of VIUA, Mikhnevo station of the Donbass RR, 80 km south of Moscow	563		low	4. 0	1. 3
	145		"	3. 9	1. 1
Novozybskovskaya experimental station of VIUA, Bryanskaya oblast'	II	sandy	high	4. 8	20. 0
	I		medium	4. 0.	12. 5
	III		low	4. 5	11. 5

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[a] Dark-colored sod-podzolic soil

Weighed portions of sod-podzolic and silty clay loam soils from the TsOS, VIUA (All-Union Institute of Fertilizers and Soil Science) (Sample No. 562) were treated with mixed solutions: 0. 002 N $CaCl_2$ + KH_2PO_4 with various concentrations of P_2O_5. The soil-solution ratio was 1:2. 5. The reaction time was one hour. The results of the P_2O_5 determinations are given in Table 2.

Data in the table show that the magnitude of the critical equilibrium concentration (0. 17 mg of P_2O_5/1) is close to the equilibrium concentration of P_2O_5 as obtained without increasing the phosphate in the solution (0. 15 mg/1). Small differences between these magnitudes were also noted in the paper by Demolon and Barbier (7) in the case of water extracts. In the case of acidic extracts, the differences were frequently negligible.

On the basis of the preceding data we consider it unnecessary to make any distinction between the critical equilibrium concentration

Table 2

Change in the P_2O_5 concentration in the solution as a result of its reaction with the soil

Solution No.	P_2O_5 concentration in solution, mg/1			Amount of P_2O_5 adsorbed by soil, mg/100 g of soil
	Original	Equilibrium	Change ±	
1	0	0. 15	+ 0. 15	--
2	0. 08	0. 17	+ 0. 07	--
3	0. 15	0. 17	+ 0. 02	--
4	0. 17	0. 17	0	--
5	0. 19	0. 17	- 0. 02	--
6	0. 24	0. 17	- 0. 07	0. 02
7	0. 81	0. 19	- 0. 62	0. 16
8	1. 97	0. 19	- 1. 78	0. 44
9	4. 02	0. 25	- 3. 77	0. 94
10	12. 54	0. 56	-11. 98	2. 99

as used by Demolon and the usual equilibrium concentration of P_2O_5 in water or salt extract, which will henceforth be used in this article.

Some remarks should be made on the basic laws governing the change in the P_2O_5 concentration in water or salt solution during its reaction with the soil.

1. If the P_2O_5 concentration in the original solution is higher than the equilibrium concentration, the soil adsorbs P_2O_5 from the solution. 2. If the P_2O_5 concentration in the original solution is lower than the equilibrium concentration, the P_2O_5 moves from the soil to the solution. 3. Adsorption of phosphate ions by the soil from the solution is accompanied by an increase in the equilibrium concentration of P_2O_5 as may be seen from the data in Table 1. In the original soil, the P_2O_5 concentration is 0.15 mg/l. If the soil adsorbs 0.2 mg of P_2O_5 per 100 g of soil (see Solution No. 7), the equilibrium concentration of P_2O_5 increases to 0.19 mg/l; if the soil adsorbs 3 mg of P_2O_5 per 100 g of soil, the equilibrium concentration increases sharply to 0.56 mg/l (see Solution No. 10). 4. A decrease in the amount of mobile P_2O_5 in the soil is accompanied by a lowering of the equilibrium concentration of P_2O_5. This statement is fully confirmed by the results of the experiment with the anionite (see below).

These four experimentally established statements, will serve as the basis for examining the process of the interaction between two soils.

Interaction Between Two Soils

Let two soils interact with each other through a solution:

$$\text{soil I} \rightleftharpoons \text{solution} \rightleftharpoons \text{soil II}.$$

The intermediate solution may be a neutral salt solution, such as a dilute solution of calcium chloride. There are two cases to be considered:

First Case. The equilibrium concentration of P_2O_5 in the salt solution for soil I (C_1) is higher than for soil II (C_2) -- that is, $C_1 > C_2$.

Let the P_2O_5 concentration in the solution at the moment when the reaction begins be equal to C_1 -- that is, to the equilibrium concentration for soil I. Then at the initial moment the soil will be in mobile equilibrium with the solution. At the same time, the solution will not be in equilibrium with soil II, since the concentration of P_2O_5 in the solution is higher than the "equilibrium" for soil II. Consequently, during the interaction with the original solution, soil II will adsorb P_2O_5 and its concentration in the solution will diminish, approaching the equilibrium for soil II. But then soil I will not be in equilibrium with the solution, since the concentration of P_2O_5 in the altered solution will at that time be lower than the equilibrium for this soil. This is the explanation for the movement of phosphate ions from soil I into the solution. This increase in the concentration of phosphate ions in the solution again causes them to be adsorbed by soil II, and so on. Thus the phosphate ions will move spontaneously from soil II. It is obvious that the phosphate level of soil I is higher than that of soil II.

In the process described, the phosphorus content in soil I will be decreased and will in turn produce a decrease in the equilibrium concentration of P_2O_5. At the same time, soil II will adsorb phosphate ions and thus cause the equilibrium concentration to rise above that of the soil in its original state. In the end, the solution that was at equilibrium for soil I will also be at equilibrium for soil II. At this point there will be a phosphate equilibrium throughout the whole system: soil I - solution - soil II. This means that the phosphate levels of these soils have been equalized.

Second Case. The equilibrium concentration is the same for both soils. By the same kind of reasoning it may be shown that the phosphate levels of both soils are already equal at the initial moment.

Thus the two magnitudes -- a) the phosphate level of the soil and b) the equilibrium concentration of P_2O_5 in the given salt solution -- are functionally interrelated. It follows from this that the equilibrium concentration of P_2O_5 in the extract from the soil may be used as an index of the phosphate level as a property of the soil's solid phase. The soil extract, however, must be such that during its interaction with the soil there is practically no change in the phosphate condition of the soil itself; otherwise the phosphate level will not be that of the soil but that of the soil as changed during the process of the reaction. Water and salt extracts with a close ratio of soil to solution will meet this requirement.

Relationship Between the Quantities Obtained

The magnitude of the P_2O_5 concentration cannot serve as a numerical expression of the soil's phosphate level except for some arbitrary level taken as zero. It may be assumed, by analogy with the chemical potential, that the "phosphate level" and the "concentration" are related logarithmically. The magnitudes of the P_2O_5 concentrations, however, make it possible to find the relative differences between two soils being compared in regard to their phosphate levels, and to judge the extent of these differences. This is quite sufficient for a comparative study of the soils.

Salt Effect. The P_2O_5 concentration in water and salt extracts from soils depends not only on the phosphate level of the soil, but also on the salt content of the solution (type of salt and concentration). This salt effect has been pointed out in a number of papers (6, 8, etc.).

If various soils are to be compared for the magnitudes of their equilibrium concentrations of P_2O_5, the original solutions for the preparation of the extracts must be the same in the case of all the soils to be compared. However, this does not always result in completely comparable extracts. The effect of the salt content of the solution on the equilibrium concentration of P_2O_5 (the salt effect) may not be the same for different soils.

The foregoing statements may be clarified as follows: for two soil samples, a chernozem and a sod-podzolic soil, the following respective P_2O_5 concentrations were obtained, in mg/1: a) in 0.01 N $CaCl_2$ extract, 0.08 and 0.09; b) in 0.03 N K_2SO_4 extract, 0.10 and 0.17. To judge by the $CaCl_2$ extract, both soils are practically the same in regard to their phosphate levels, whereas according to the data from the K_2SO_4 extract the phosphate levels of the two soils being compared are very different.

The case has just been cited in which soils of two different soil groups were compared. Such differences did not appear in comparing soils belonging to the same genetic group. The problem of which salt extract to use in order to encompass a broad group of soils, including different genetic groups, must be regarded as still unsolved.[2]

Phosphate Phases of the Soil

The concept of the "phosphate level" is related to the soil as a whole. But one and the same soil will contain different phosphorus minerals representing separate solid phases. We believe that the various phosphorus minerals in the soil affecting the concentration of phosphate ions in the solution are probably in equilibrium with each other. Thus the concentration of phosphate ions when at equilibrium for one of these compounds, will also be at equilibrium for all those remaining. Under such conditions these compounds representing separate phases have the same phosphate level; this level will be the phosphate level that is determined for the soil as a whole.

This assumption of an equilibrium between a number of phosphate phases appears to be a likely one for the following reasons. The separate phosphate phases interact with each other through a solution. Phosphate ions move from the phase with the higher to that with the lower phosphate level, until the phosphate levels of both phases have been equalized or new phases have been produced with the same phosphate level (by analogy with the interaction between two soils, as considered above). This is probable especially in the case of isotope-exchange phosphates which are distinguished for their high rate of exchange.

In connection with this problem of the equilibrium of different phosphate phases, mention should be made of the paper by Rathje (9), which examines the equilibrium conditions of the phosphate systems in the hydroxyl-apatite phosphates of ions and aluminum.

The equilibrium of the phosphate phases should not be considered applicable to all the soil phosphates. It is quite probable that soils may contain phosphates with especially low solubilities and very slow rates of release of phosphate ions into solution. These include, for example, fluor-apatite with a dense crystalline structure, as well as phosphates that are practically inaccessible to the exchange process because they are "packed" into microaggregates or blocked off by organic substances, etc. Such compounds have no noticeable influence on the concentration of phosphate ions in the solution and will not affect the phosphate level of the soil as a whole.

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[2] A $CaCl_2$ extract may be used as a "standard" for a broad group of soils. In deciding on the conception of $CaCl_2$ for this extract, the following must be taken into account: extracts with a high salt concentration have the practical advantage that they are easily filtered; on the other hand, the equilibrium concentration of P_2O_5 is higher in the more dilute extracts. By using a 0.02 N $CaCl_2$ extract, as suggested by Schofield, it is impossible to detect soils with a very low phosphate level. For this reason it is suitable to use a more dilute solution of $CaCl_2$, on the order of 0.002-0.003 N, as the standard extract for an extensive group of soils.

CHANGES IN THE PHOSPHATE LEVEL IN RELATION TO THE AMOUNTS OF PHOSPHORUS EXTRACTED FROM THE SOIL BY MEANS OF AN ANIONITE

A method has recently been developed to extract mobile phosphorus from the soil by means of an anionite (Amer, Bouldin, Black and Duke, [5]). It is possible by this method to remove considerable amounts of mobile phosphorus without altering the concentration of hydrogen and calcium ions in the solution. This has great advantages over the usual method of removing phosphorus from the soil by means of acidic extracts.

The mechanism by which the anionite (saturated with Cl ions) adsorbs phosphorus from the soil may be represented as follows: phosphate ions move from the soil into the solution; they are then adsorbed by the anionite through an exchange of Cl ions in the anionite for phosphate ions in the solution. The lowering of the P_2O_5 concentration in the solution causes a new transfer of phosphorus from the soil and renewed adsorption by the anionite.

An experiment was done with sod-podzolic soil to establish the connection between the amount of phosphorus extracted by the anionite and the magnitude of the P_2O_5 concentration in the water extract from the soil (after removal of the anionite).

Phosphorus was removed from the soil by an anionite, according to the method described in the paper by Amer, et al. (5). The soil sample was air-dried and passed through a sieve with 0. 25 mm openings. The EDE-10 anionite was first treated with 1 N hydrochloric acid and then washed for a long time with water to remove the acid (reaction with methyl orange), thus obtaining an anionite saturated with chlorine ions.

An anionite fraction ranging from 1 to 0. 4 mm in diameter was used to remove P_2O_5 from the soil. Weighed portions of soil and anionite were mixed in a small flask and distilled water was then added. After a specified time had elapsed for the reaction of the soil with the anionite, the contents of the flask were passed through a sieve with 0. 25 mm openings to separate the soil from the anionite: the soil particles passed through the sieve openings, whereas the anionite grains were retained. The anionite was washed with water. The wash water from the main mass of the soil that had passed through the sieve was then separated from the soil in an ultrafiltration funnel (Sigmondi) with a dense paper filter. The amount of P_2O_5 in the wash water did not exceed 0-1 mg of P_2O_5 per 100 g of soil. The soil (after removal of leached water) was maintained in its moist condition for two days. Water extracts from the soil were then prepared and the concentration of P_2O_5 in them was determined.

The anionite separated from the soil was treated with an alkaline solution (0. 6 N NaOH). Preliminary tests had shown that all the phosphorus adsorbed by anionite could be removed this way. The phosphorus content was then determined colorimetrically, as indicated above, after the excess alkali had been neutralized by hydrochloric acid.

In order to obtain soil samples with various degrees of "impoverishment" in phosphorus -- in other words, to remove different amounts of phosphorus with the anionite -- two methods were used: 1) the ratios of the weighed portions of soil and anionite (Table 3) were changed, while the time of the interaction was kept constant at ten 24-hour periods, with periodic shaking; 2) the time of the interaction was changed and the soil-anionite ratio was kept at 8:1 (10 g of anionite were used for every 80 g of soil). In this case there was continuous agitation of the soil and anionite mixture. The resulting data are given in Table 3.

As may be seen in Table 3, very large amounts of P_2O_5 were removed from the soil, up to 10 mg per 100 g of soil. It must be emphasized once more that during this process there was practically no change in soil acidity. The pH was 5. 68 in the water suspension after removal of the anionite, whereas in the original soil the pH was 5. 75.

As the quantity of phosphorus extracted from the soil increased, there was a regular decrease in the P_2O_5 concentration in the water extract and, consequently, a decrease in the phosphate level of the soil

The amount of mobile P_2O_5. The quantity of mobile P_2O_5 extracted by the anionite may serve as an index of the amount of mobile P_2O_5 in the soil. Different P_2O_5 contents were obtained depending on the means and the length of time of the extraction. This quantity becomes a definite one if it indicates the phosphate level that must be reached as a result of extracting a given amount of phosphorus from the soil. In comparing various soils, this conditional (zero) level is taken to be the same for all the soils, as may be judged by the magnitude of the P_2O_5 concentration in the equilibrium solution. At this conditional zero level, the amount of mobile P_2O_5 is also conditionally equal to zero.

Turning again to Table 3, we see that the conditional zero level corresponds to the smallest concentration of P_2O_5 in the solution -- 0. 25 mg/l. This phosphate level is reached after a 20-hour interaction between the soil and the anionite (weighed portion 4b). In this

Table 3

Extraction of P_2O_5 from soil by anionite
Highly cultivated sod-podzolic soil from
TsOS VIUA (Sample No. 561)

Weighed Sample No.	Soil-anionite ratio	Time of reaction with anionite	P_2O_5 extracted by anionite, mg/100 g soil	Concentration of P_2O_5 in water extract from soil, mg/l
A. With a constant time of reaction (and periodic shaking)				
1a	original soil	--	--	0.97
2a	16:1	10 24-hr periods	5.3	0.48
3a	8:1	" "	6.0	0.43
4a	4:1	" "	8.0	0.39
5a	2:1	" "	10.3	0.25
B. With a constant soil-anionite ratio (and continuous shaking)				
1b	original soil	--	--	0.97
2b	8:1	1 hr	3.6	0.57
3b	8:1	5 hrs	8.5	0.32
4b	8:1	20 hrs	9.4	0.25

process, 9.4 mg of P_2O_5 were removed for every 100 g of soil. Consequently, this is also the amount of mobile P_2O_5 in the soil at this conditional zero phosphate level. With another extraction method but at the same conditional phosphate level (weighed sample 5a), the amount of mobile P_2O_5 was similar (10.3 mg per 100 g of soil).

CHANGE IN THE PHOSPHATE LEVEL OF THE SOIL AS A RESULT OF THE REMOVAL OF PHOSPHORUS BY PLANTS

To find the answer to the foregoing question an experiment was conducted with spring wheat in three soils (in 1956). The magnitude of the P_2O_5 concentration in the water extract was used to indicate the phosphate level of the soil. In carrying out this experiment, the problem arose of removing the greatest possible amount of P_2O_5 per unit weight of soil: with this in mind, small plant pots holding 2 kg of soil were used. The soil moisture was maintained at 80% of the total moisture-holding capacity. Nitrogen in the amounts of 0.2 g of N as KNO_3 per pot was added; one-third of the total amount for each pot was added per application. No phosphorus was added. Sod-podzolic clay loams under various degrees of cultivation (TsOS, VIUA) were chosen for the experiment. The results are shown in Table 4.

The following two statements may be made, on the basis of the data cited in Table 4:

1. There is a relationship between the amount of phosphorus removed by the spring wheat and the P_2O_5 concentration in the water extract. The amounts of phosphorus removed was higher in the soils characterized by a higher P_2O_5 concentration in the extract and thus by a higher phosphate level. 2. The removal of phosphorus from the soil by the spring wheat was accompanied by a sharp drop in the P_2O_5 concentration in the water extract from the soil. This shows that the plants decreased the phosphate level of the soil. It should be mentioned here that similar data showing a decrease in the content of soluble P_2O_5 during the course of an oat experiment were obtained earlier by Chirikov (3, p. 248).

The foregoing experiment was repeated in 1957 on a somewhat broader scale, on different soils, and with another plant -- oats.[3] Sandy soils from the Novozybkovskaya Experimental Station were used along with the sod-podzolic clay loams of the TsOS, VIUA. The procedures in this plant experiment (size of pots, moisture, amounts of nitrogen added) were the same as in 1956. In the case of the soil "without vegetation" and "after harvest," the

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[3] This experiment was carried out by the author's colleague, N.M. Glazunova.

Table 4

Removal of phosphorus by spring wheat and change in the concentration of P_2O_5 in the soil extract

Sample No.	Degree of cultivation	Yield, g per pot		Removal of P_2O_5, mg/100 g of soil	P_2O_5 in water extract from soil, mg/l	
		Total weight	Grain		Original	After harvest
561	high	29.2	10.7	8.4	0.97	0.27
562	medium	30.1	11.8	5.2	0.26	0.022
563	low	9.2	4.3	1.7	0.034	0.011

Table 5

Removal of phosphorus by oats and change in the concentration of P_2O_5 in the soil extract

Soil	Sample No.	Degree of cultivation	Without phosphorus					With phosphorus yield, g per pot	
			Yield, g per pot		Removal of P_2O_5, mg/100 g of soil	P_2O_5 in 0.03 N K_2SO_4 ext. fr. soil, mg/l			
			Total dry wt.	Grain		Without vege.	After harvest	Total dry weight	Grain
Sod-podzolic clay loam of TsOS, VIUA	144	high	19.8	7.1	5.8	0.33	0.11	21.9	8.0
	143	medium	28.5	8.9	4.9	0.16	0.070	30.3	9.8
	142	"	15.6	4.7	2.8	0.051	0.027	22.4	9.0
	141	"	17.0	5.5	2.6	0.052	0.023	23.1	8.1
	145a	low	6.8	1.9	1.0	0.027	<0.01	21.2	6.9
	145b	low[a]	8.8	2.1	1.2	0.022	<0.01	21.3	8.0
Sod-podzolic sandy soil of Novozybkovskaya Experimental Station	II	high	21.7	8.2	6.4	0.72	0.26	21.5	8.9
	I	medium	17.2	6.4	3.3	0.42	0.15	19.8	7.0
	III	low	9.2	2.9	2.0	0.09	0.038	19.0	6.3

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[a] Calcium carbonate up to half of the hydrolytic acidity was added into the soil before the latter was tamped into the pot.

concentration of P_2O_5 was determined in a 0.03 N K_2SO_4 extract. The results are given in Table 5.

The data in Table 5 completely confirm the conclusions made on the basis of the experiment in 1956. In all the soils, the removal of phosphorus by the plants was accompanied by a lowering of the phosphate level.

Was the removal of phosphorus in the foregoing experiments entirely at the expense of a lowering of the phosphate level, or was it to some degree connected with the utilization of other sources of phosphorus that did not affect the P_2O_5 concentration in the equilibrium solution and thus had nothing to do with the phosphate level? Such other sources would include organic phosphorus compounds, for example, as well as the particularly insoluble mineral compounds of phosphorus.

To answer this question, the amount of phosphorus removed from the soil by the plants must be compared with the quantity of mobile phosphorus in the soil as determined by the use of the anionite. Such a comparison may be made if the following condition is observed: the final phosphate levels of the soil, both after the harvest and after the removal of phosphorus by the anionite, must be the same -- that is, the equilibrium concentrations of P_2O_5 in the extracts (water or salt) from the soil must be the same. In order to observe this condition, such an amount of P_2O_5 must be removed by means of the anionite so that the concentration in the equilibrium solution is close to that obtained in the experiment with the plants.

Table 6 shows a comparison of these quantities for two highly cultivated sod-podzolic clay loam soils of TsOS, VIUA: Samples 561 and 146. In the case of Sample No. 561, data from Table 3 were used (anionite experiment) in conjunction with data from Table 4 (spring wheat experiment).

Table 6

Comparison of the amounts of phosphorus absorbed by plants and by the anionite

Sample No.	Year of experiment	Crop	Plants		Anionite	
			Removal of P_2O_5 mg/100 g	P_2O_5 concentration, mg/l[a]	P_2O_5 removed, mg/100 g	P_2O_5 concentration, mg/l[a]
561	1956	Spring wheat	8.4	0.27	10.3	0.24
146	1957	Oats	5.4	0.09	5.1	0.08

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[a] The P_2O_5 concentration in the 1956 experiment was determined in the water extract; in the 1957 experiment this was determined in a 0.03 N K_2SO_4 extract.

In the 1956 experiment the amount of P_2O_5 removed by the anionite was also greater than that removed by the plants, but the magnitudes obtained were of the same order. In the 1957 experiment the amounts of P_2O_5 removed by the plants and by the anionite were practically identical. The P_2O_5 concentrations in the extracts from the soil after the removal of phosphorus by the anionite were also the same.

The data obtained from the experiments suggest a certain analogy between the processes involved in the phosphate removal by the plants and by the anionite. This analogy cannot, however, be carried too far. The adsorption of phosphorus from the soil by the root systems represents an active process associated with the exchange of elements within the plants and with the life-activity of the plants as a whole, and cannot be identified with the physicochemical process of adsorption that takes place in the case of the anionite. Both processes, nevertheless, have these common features: phosphate ions are removed from the solution; their concentration is lowered; and this lowering produces a movement of phosphate ions from the soil into the solution. The adsorption of phosphorus by the anionite or by the plants results in a new movement of phosphorus from the solid phase into the solution, and so on. This mechanism by which phosphorus is removed from the soil has been pointed out earlier (3, p. 185; 4, p. 278; etc.) and may be understood in a much more concrete form after the experiments with the anionite.

In the case of this mechanism by which the phosphate ions go from the soil into the solution, the phosphate level determined the soil's ability to give up phosphate ions into solution. Here the P_2O_5 concentration in the water or salt extract is a very important indication.

Along with the movement of phosphate ions from the soil into the solution, the following processes may also be assumed to take place:

1. A dissolving action by the root secretions on the more insoluble phosphate minerals in the soil. This involves the compounds which because of their low solubility or their slow rate of solution cannot for all practical purposes spontaneously go into the solution when the P_2O_5 concentration in it is lowered.
2. An increase in the mobility of the phosphorus in the organic and mineral compounds through the activity of the microflora surrounding the roots during the growth of the plants.

Neither the insoluble mineral compounds in the soil nor the organic compounds of phosphorus have any direct effect on the phosphate level of the soil. The increase in the mobility of these compounds associated with the movement of phosphate ions into the solution may, however, cause a rise in the phosphate level.

Returning to the previous data considered, we again see that the removal of phosphorus by plants is accompanied by a lowering of the soil's phosphate level, indicating that the first process (associated with the decrease in the phosphate level) plays a very important role here. These statements, however, are made only with regard to a very limited group of soils (sod-podzolic) and crops (oats and spring wheat). For this reason we refrain from making any broader generalizations.

RESTORATION OF THE PHOSPHATE LEVEL LOWERED AS A RESULT OF PLANT ACTIVITY

Studies were made of the soil taken from the pots after the crop had been harvested. A vegetation experiment with oats was conducted in 1955 on a highly cultivated sod-podzolic soil from the TsOS, VIUA (specimen 551). The procedures used in this experiment were the same as described in the 1956 experiment.

The amount of phosphorus removed by the plants was very large: for the soil not fertilized with phosphorus this came to 6.6 mg of P_2O_5 per 100 g of soil, and for the soil fertilized with phosphorus, to 8.0 mg. The P_2O_5 concentration in the 0.03 N K_2SO_4 extract from the soil after the harvest was considerably smaller than before. Thus the following question was suggested: is the phosphate level of the soil raised during the period after the crop has been harvested? To determine this, the roots were removed from the soil after the harvest and the soil was kept in a friable and moist condition ("fallowed"). More moisture was added as the soil dried out. During the period of the experiment the soil moisture content varied from 13 to 23%.

The magnitude of the P_2O_5 concentration in a 0.03 N K_2SO_4 extract was taken as the index of the soil's phosphate level. The results of determinations of the P_2O_5 content after specific time periods are given in Table 7.

The data in Table 7 show that the phosphate level which had fallen sharply as a result of the removal of phosphorus by the plants was renewed, but that this renewal took place slowly. In the case of non-fertilized soil, after a month and a half the P_2O_5 concentration was somewhat higher, but far from the original magnitude. In fertilized soil, even after five months the change was almost negligible. After eleven months, however, the P_2O_5 concentration in the 0.03 N K_2SO_4 extract had almost reached its original level -- the level at which it had been before the vegetation experiment. This indicates that the phosphate level which falls through the removal of phosphorus by plants is restored gradually. This removal may be associated with the following processes: 1) increase in the mobility of the phosphorus in the organic phosphorus compounds through microbiological activity, and 2) physicochemical processes involving the movement of phosphate ions from the more interior layers of soil particles to their surface layers, which have been impoverished by the removal of phosphorus by plants. In the latter case there is a disruption, so to speak, of the equilibrium between the phosphate ions on the surfaces of soil particles and those in their interior layers.

CONCLUSIONS

1. The term "phosphate level of the soil" is defined as follows: in the interaction of two soils through a solution, phosphate ions pass spontaneously from the soil with the higher to the soil with the lower phosphate level; when this system is in equilibrium, the phosphate levels of the soils are equal. Thus it follows that the phosphate level characterizes the mobility of the soil's phosphates as a whole.

The phosphate level of the soil is a concept analogous to the phosphate potential of the soil

Table 7

Effect of "fallowing" on the phosphate level of the soil

Length of time (after harvest)	P_2O_5 in 0.03 N K_2SO_4 extract, mg/l	
	Soil not fertilized with phosphorus	Soil fertilized with phosphorus
2 days	0.06	0.12
1.5 months	0.13	--
5 "	--	0.16
11 "	0.56	0.58
Original soil, before tamping in the pot experiment, 1955	0.58	0.62

as used by Schofield, but more general and less strictly defined.

2. The criterion of the phosphate level is the magnitude of the P_2O_5 concentration in the salt or water extract (when there is a narrow soil-solution ratio). This magnitude, which is not a numerical expression of the phosphate level, nevertheless serves as a means of distinguishing the relative differences between soils.

3. When phosphorus is removed from the soil by means of an anionite there is a decrease in the magnitude of the equilibrium concentration of P_2O_5 in the water extract from the soil -- i. e., a drop in the phosphate level of the soil. In determining the amounts of mobile P_2O_5 in soils by means of an anionite, comparable results may be obtained if the removal of P_2O_5 is kept up until the phosphate level that was taken as the conditional zero level has been reached.

4. During the pot experiments with oats and spring wheat, decreases were observed in the magnitudes of the P_2O_5 concentrations in water and salt extracts from the soil -- i. e., decreases in the soil's phosphate level connected with the removal of phosphorus by plants. This happened without exception in all the soils investigated.

The quantities of phosphorus extracted from the soil by the anionite and by the plants were on the same order (as long as the soil's phosphate level was the same after the extraction); these data suggest some similarity between the processes involved in the removal of phosphorus by plants and by the anionite. Their common features are: phosphate ions are removed from solution; their concentration in the solution drops; and that this lowering causes a movement of phosphate ions from the soil into the solution.

5. The phosphate level which has dropped as a result of the removal of phosphorus by the plants is restored if the soil is subsequently maintained for a long time in a friable and moist condition ("fallowing").

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THE DECOMPOSITION OF FULVIC ACIDS BY MICROORGANISMS

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The decomposition of humus by microorganisms is one of the most important and at the same time most complicated problems in soil microbiology. Its complexity is due not only to the relative stability of these substances under the microbial action but also to the lack of homogeneity in their chemical composition and to the many forms of compounds with mineral substances in the soil.

According to the data in Tyurin (17, 18), who was the first to present a broad study of the geographic laws governing humus formation in the USSR (see also Konova, 3, 4, Ponomareva, 13, and others), different forms of humus substances predominate in different soil groups. In speaking of the humus decomposition by microorganisms one must therefore distinguish accurately between the substances being discussed. The information on this subject in the literature relates only to the decomposition of humic acids and their salts primarily by humates of calcium and sodium (2, 5, 22, 23, etc.). The problem of the decomposition of fulvic acids by microorganisms has not even been touched upon up to this time in spite of the fact that fulvic acids are the basic and quantitatively predominant group of humus substances in the soils of the podzolic zone. The content of fulvic acids in podzolic soils and krasnozems is two or three times greater than the content of humic acids. Ponomareva (12) indicates that the absolute amounts of fulvic acids in the profile of the humus-illuvial podzolic soils are three to five times greater than the amounts of humic acid. The humus illuvial horizons of sandy podzols, in which the fulvic acids are accumulated as complex compounds with hydrates of sesquioxides, are especially characteristic natural accumulations of fulvic acids. Their content increases with the increase in the soil moisture and may in individual cases reach more than 50% of the total soil weight (12).

According to the Soviet soil literature, fulvic acids and their role in soil formation have been studied mainly by Tyurin (16, 17, 18) and Ponomareva (9, 10, 11, 12). The papers by these authors describe the methods of separating fulvic acids and characterize their composition and properties, occurrences in soils and role in soil formation.

The literature contains no data on the decomposition of fulvic acids by microorganisms, except for mention of their extraordinary stability under the action of microbes. V. V. Ponomareva (12), for example, noted that under laboratory conditions the complex compounds of fulvic acids with sesquioxides may be retained in a moist condition for a very long time without undergoing any noticeable changes.

It is difficult, however, to imagine that there could be organic substances which are completely non-decomposable to microbic action. In undertaking the present investigation I have therefore assumed that the process of biological decomposition of fulvic acids must exist and set the task of discovering the main factors which produced it.

In the investigation, it was kept in mind that fulvic acids could exist in the soil both as solutions and in the form of organic mineral gels. The latter form may be considered the predominant one, whereas the water-soluble forms of fulvic acids in the soil must be ephemeral, since they are either removed from the soil by atmospheric precipitation or else fixed by becoming gels. Thus the most interesting problem is the study of the decomposition by microorganisms of the latter forms of fulvic acids. Fulvic acids were extracted from the B horizon of a single soil taken from the area of the Karelian isthmus (humus-illuvial podzol).[1] In obtaining fulvate gels acidic extracts were used which were prepared by allowing 50 g of soil to stand for 24 hours in a liter of 0.1 N solution of HCl. After filtration, the fulvic acids were precipitated by neutralizing the extract with a solution of NaOH up to a pH of about 5.0. In this process there was an almost complete precipitation from solution of the complexes of fulvic acids with sesquioxides. The sediment was filtered and freed of salts by being carefully washed with water. The washed gel was placed in a flask which contained a small amount of water, agitated until a homogeneous consistency was obtained, and then used in sterilized and unsterilized forms for the experiment. The sterilization was done at a pressure of one-half atmosphere for half an hour.

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[1] In preparations of fulvic acids the author consulted with V. V. Ponomareva, to whom she extends her sincere thanks.

The procedure in the experiment on the decomposition of fulvate gels was as follows. A 1.5% aqueous agar was poured into a Petri dish; after cooling, about 0.1 ml of soil suspensions from various cultures and about 1 ml of fairly thick fulvate gel were poured on the surface of the agar. (The agar was first steeped in water for several days.) The Petri dish was lightly agitated and shaken in order to mix the gel with the inoculate and to distribute it evenly over the surface of the agar. The consistency and the amount of the gel had to be such that when the Petri dish was turned over, the gel did not stick to the edges of the dish's cover. To keep the gel from drying, the filled dishes were placed in a moist room.

Assuming that the decomposition of fulvic acids by microorganisms might require the presence in the medium of other easily assimilated substances, a dense synthetic medium (of the following composition) was used in addition to aqueous agar in order to find the factors causing the process under investigation:

$(NH_4)_2HPO_4$, 0.1%; KH_2PO_4, 0.01%;
Na_2HPO_4, 0.01%; $MgSO_4$, 0.006%;
$CaCl_2$, 0.002%; NaCl, 0.002%; glucose, 1.0%;
agar agar, 1.5%.

The fulvate gel and the inoculum were poured on the medium surface in the manner described previously. For the inoculum, the soils were primarily from the podzolic zone (these were mainly virgin humus-illuvial podzols and sod-podzolic soils of the Leningrad Oblast') and of krasnozems. All inoculation was replicated six and ten times.[2]

After inoculation of the fulvate gel, depressions or pitted zones appeared on the surface of the gel, usually seven to ten days after the beginning of the experiment and sometimes also later (up to one or one-and-a-half months). In most cases these almost had the shapes of circles. When the Petri dishes were examined in a penetrating light, one could see that the layer of gel in the depressions had become considerably thinner, although it was not completely removed. It was more convenient to examine the pitted zones after placing the dish on a sheet of black paper and removing the lid. In this position it was easy to see that the pitted zones had considerable depth. Figure 1a shows a dish with a pitted zone photographed against a black background. An idea of the degree of decomposition of the gel can be obtained from Figure 1b, which shows the edge of a large pitted zone photographed with moderate magnification under the microscope. The light part of the photograph represents that part of the dish in which the gel has been strongly decomposed; the dark part of the field is the gel outside the pitted zone. When aqueous agar was used, in most cases no colonies of microorganisms could be observed on the gel surface. It appeared that the gel was sterilized and that the depressions which formed in it were also sterile. The small zones of pitting which formed at the beginning, however, began to increase in size and finally often merged with each other. To find the intensity of this process, several daily measurements of the diameters of these zones were made. It appeared that, under favorable moisture conditions in the gel, the zones could increase very rapidly. The data from several measurements are shown as an illustration (see Table 1).

These data show that the diameter of a pitted zone could multiply one-and-a-half to three times during the course of 24 hours. This is a confirmation that the process was biological in nature, even though the zones did not always grow at such speed; in some cases several days or even a week were required for the zones to double their size.

After examining the Petri dishes with the pitted zones under the microscope, it was concluded that the zones are not formed by any bacterial colony and that no accumulations of cells could be seen in them. At the very edge of the gel surrounding the pitted zone there were dense, tightly squeezed cells of amoebae. To make a closer examination of the accumulations of amoebae on the periphery of the pitted zones, it was necessary to dissolve the fulvate gel with an 0.1 N solution of hydrochloric or sulfuric acid. When acted upon by the acid, the individual cells began to be pressed closer together and to become angular or even completely circular, but did not change their positions. This is illustrated by microphotographs taken with large and small magnifications under the microscope (Fig. 2).

The illustrations show that the amoebae

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[2] The soils used will not be described in detail in this article, which is limited to a very general description of the mechanism in the decomposition of fulvic acids and of the factors that cause it, without touching on the problem of how this process is distributed throughout various soil groups.

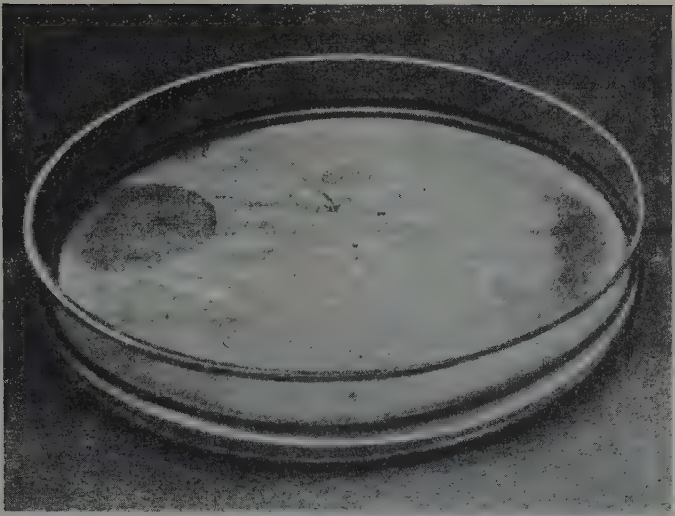

Fig. 1a. General view of Petri dish with pitted zones.

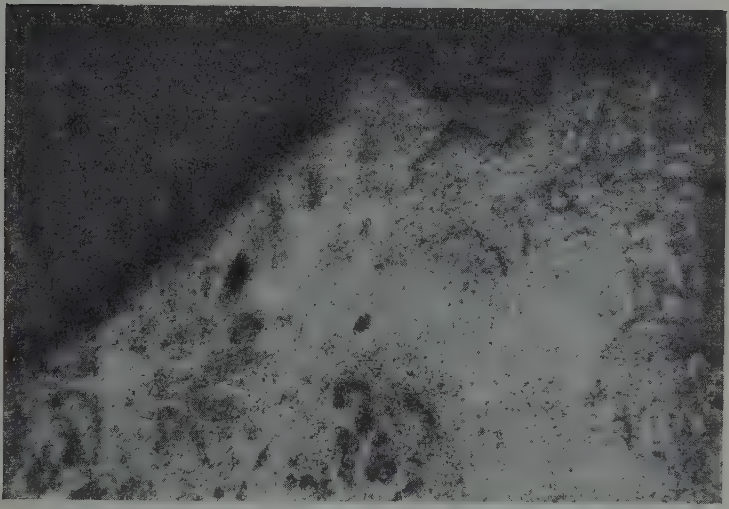

Fig. 1b. The edge of a pitted zone as seen under the microscope (magnification x 56).

surround the pitted zone in a narrow ring of living matter. Pressed closely against each other and against the untouched part of the gel at the edge of the zone, they consume the gel. The surface of the gel which has not been destroyed by amoebae (Fig. 2b) is covered by a very thin film of bacteria, which could not be seen at all before the dissolution of the gel. In the pitted zones there are very few bacterial cells, whereas outside the zone they are extremely numerous. Moving in a dense front from the common center toward the periphery of the pitted zone, the amoebae simultaneously destroy both the bacterial bodies and the fulvic acids, thus causing the pitted zones to increase.

It is well known that amoebae feed mainly on solid food, incorporating the individual food particles into their bodies and digesting them within the cell. Under the conditions of this experiment, the fulvate gel presented a smooth surface and could therefore not be incorporated into the individual cells. Evidently the amoebae, collecting in large groups, digested it together by secreting the necessary digestive substances from their cells into the surrounding medium. With such a large accumulation

Table 1

Growth rate of the pitted zones

Zone No.	Diameter on 12th day	Diameter on 13th day	Zone No.	Diameter on 12th day	Diameter on 13th day
	millimeters			millimeters	
1	2	4	7	2	4
2	3.5	7	8	11	16
3	3	6	9	3	8
4	5	10	10	4	10
5	2.5	6	11	3	9
6	10	23	12	4	6

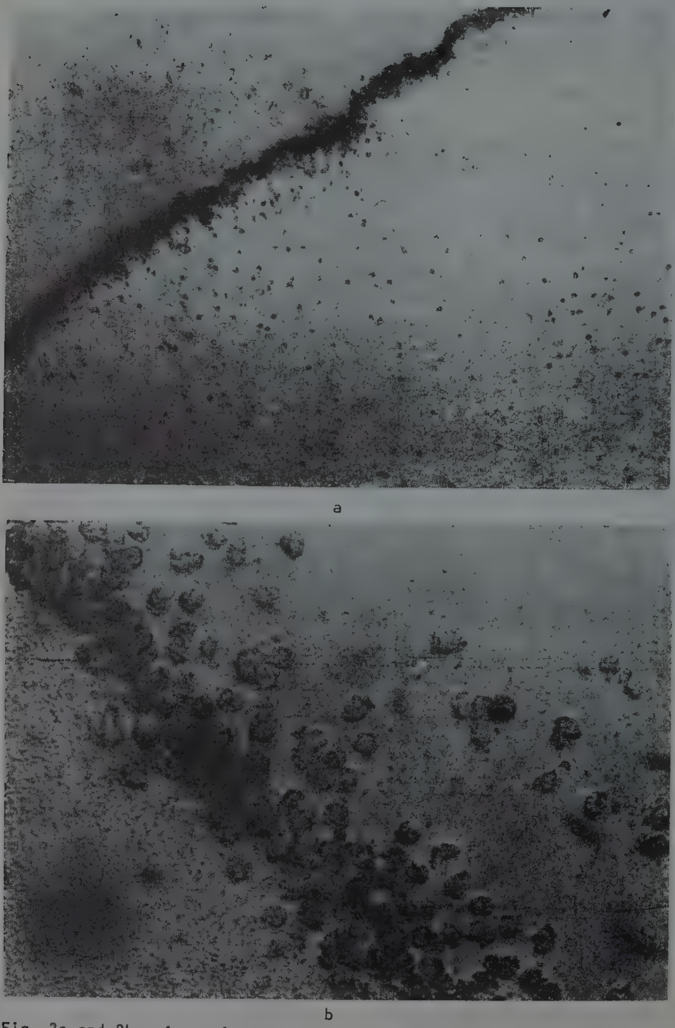

Fig. 2a and 2b. Accumulations of amoebae at the edge of a pitted zone as seen in two different magnifications (x 140 and x 630).

of amoebal cells, naturally, there was a very large concentration of the appropriate exoferments in the area where the amoebal ring joined the fulvate gel. It should be noted that the sterile and the nonsterile gels were both consumed at the same rate. Evidently sterilization has little effect on the composition and properties of these stable substances. With the course of time, if the gel dries out somewhat, the ring of amoebae along the periphery of the pitted zones may disappear. The amoebae are scattered over the surface of the dish, partly transformed into cysts, and apparently die.

When the water agar is replaced by the synthetic medium, the amoebae form in the very deep and rapidly growing zones of pitting in the dishes containing the fulvate gel. In certain cases, on the other hand, they produce almost no changes in the gel, merely forming a scarcely noticeable surface zone and feeding primarily, and sometimes entirely, on the bacteria. It is quite possible that all the amoebal species which grow in the fulvate media are not equally capable of using these substances as sources of food. In addition, the species composition of the accompanying bacteria may also be of significance.

Are the amoebae capable of decomposing the fulvic acids in pure cultures free of bacteria? To answer this question, an attempt was made to obtain such cultures by placing a thin layer of agar with a small amount of fulvate gel in small, round Perfil'yev vessels (8). These vessels have a thin lid which permits continuous observation of the object being investigated, with any magnification under the microscope and without destroying the sterility. The amoebal cells from the peripheral parts of the pitted zone were placed in droplets of water, transferred from one droplet to another by means of a capillary pipette, gradually washed free of the surrounding bacteria and placed in small vessels. No growth of the amoebae could be found in the vessels in which only amoebal cells without bacteria had been placed, whereas the amoebae began to multiply rapidly in the vessels containing both amoebae and bacteria. Apparently the amoebae require certain substances which are lacking in the fulvic acids but which exist within the bacterial bodies. Thus, under the conditions of this experiment, the amoebae could grow, and consequently also decompose the fulvic acids, only when bacteria were present as a supplementary source of food. The possibility is not excluded, however, that if the proper media are selected this process could also take place in amoebal cultures lacking bacteria. It is well known that obtaining such cultures is an extremely difficult task. Nevertheless, the literature indicates that pure cultures of certain types of amoebae have been obtained (19).

The growth of the amoebae and their decomposition of the fulvic acids (under laboratory conditions) was observed to have some relationship to the time of year. Inoculation in January and February produced no results whatever, whereas in March active cultures of amoebae were produced from the same specimens. The decomposition of the fulvic acids was most intensive and rapid during spring and autumn, when after comparatively short periods of time (seven to ten days) it was possible to observe a rapid development of the pitted zones by a number of successive inoculations of amoebae and bacterial cells from the peripheral parts of these zones into fresh fulvate gel (in either aqueous or synthetic agar). Two or three cultures were prepared from the seeding material, and from ten to twenty parallel Petri dishes were seeded simultaneously by the method described previously. In this manner, five successive inoculations were made. The inoculations from the soil samples during this period produced similar results. It is possible that all this was caused by some regular features in the growth cycle of the amoebae.

Besides the amoebae, other protozoa were also found in the synthetic medium with the fulvate gel.[3] Tiny flagellates (Bodo, Monas) and infusoria (Colpoda) were sometimes found to grow in Petri dishes. In places where these formed large accumulations on the surfaces of the gel, there appeared to be tiny depressions which looked as though they had been made by needles; the mechanism by which these pits were formed is still not clear. Examination of these depressions under the microscope showed that they were literally packed with protozoa.

In addition to the protozoa, in the Petri dishes which contained a synthetic medium in contrast to the water agar, it was possible to see numerous colonies of bacteria and actinomyces. Molds which scarcely ever appear in the water agar also sometimes grow in the synthetic medium. In spite of the quite intensive growth of these microorganisms, the author was never able to observe any decomposition of the fulvate gel around their colonies. Colonies of bacteria sometimes begin to grow beneath the layer of gel, directly on the synthetic agar. As they increase in size they destroy the gel which rolls off the colonies to form a solid ridge around them. A cursory examination of these dishes might create the false impression that the bacteria have destroyed the fulvate gel. If, however, such a colony is transferred to the surface of a fresh medium, there is no decomposition of the fulvic acids, although the bacteria here grow extremely well and form a dense mucous coating.

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[3] Not having competence the author was aided by Prof. L.K. Lozino-Lozinskiy in distinguishing the individual species in the composition of the microfauna. He also gave advice on other aspects of this paper for which the author expresses her deep gratitude.

The bacterial colonies surrounded by a solid ridge of gel attract protozoa, primarily infusoria, which eat through the bacterial bodies and then also begin to decompose the fulvic acids. Wherever these colonies are found, there is a formation of depressions with diameters greater than those of the original colonies. Nothing remains of the solid ridge of gel. The layer of gel at the edge of the depression becomes very thin, and on the surface one may see massive accumulations of amoebae, infusoria and flagellates. Probably not all of the protozoa which grow on the fulvate medium take part in the decomposition of the organic mineral complex. There is no doubt, however, that under these conditions the amoebae, and sometimes the small flagellates, take part in this process. The proof of this is the formation of iron concretions produced by microorganisms.

From one-and-a-half to four months after the seeding, both in the dishes containing water agar and in those with the synthetic medium, yellow-brown patches scarcely distinguishable with the naked eye can be seen. When these are examined under the microscope, it appears that they are accumulations of cells filled with iron. The reaction with potassium ferrocyanide in a hydrochloric acid solution shows quite clearly that these cells are surrounded by a gel of iron hydroxide. In addition to the amoebae, which often occupy the most prominent position, one may see iron-filled cells of tiny flagellates, actinomyces, and sometimes of bacteria.

With time, these iron accumulations gradually increase in size and finally become as large as the head of a pin. Sometimes the accumulations of iron-filled cells form a dense, broad band or several bands around the individual pitted zones (Fig. 3), and in certain cases they are formed within the zones. Although the ferrous gel hides the cells located within it, by turning the micrometer screw on the microscope rounded cells and cysts of protozoa may be observed.

To determine the nature of the organisms which create the iron secretions, the author, on the advice of L. K. Lozino-Lozinskiy, employed the method of germination on rice that is used in protistology. Individual iron accumulations were transferred into a Petri dish with water in which some grains of rice had been dropped. After five to ten days in the dishes, along with the bacteria one could in most cases observe a growth of amoebae and sometimes of tiny flagellates. Similar results were also obtained when iron accumulations with cells were germinated on microscope slides with sterile fulvate gel. The cells of amoebae frequently form individual iron secretions, whereas the flagellates often form peculiar colonies together with other organisms. On dissolving the iron hydroxides in hydrochloric acid, one may observe that these colonies are made up simultaneously of protozoa, bacteria, and actinomyces. Most frequently encountered in such colonies, together with the amoebae and the flagellates, were microbacteria, actinomyces and short mobile bacilli. Because of the differing composition of the groups of microorganisms that form them, the iron segregations may also have various shapes. In general, one may distinguish three basic and most frequently encountered types of such formations. The most predominant are loose accumulations of individual iron-filled cells, mainly of amoebae. The second place is occupied by compact colonies consisting of iron-filled cells of amoebae, flagellates and bacteria or of amoebae and bacteria. Finally, there are colonies which are formed of actinomyces or actinomyces and amoebae and have the general form of actinomyces colonies. Among the accumulations of the first of these types one may frequently see individual cells in various stages of being filled with iron (Fig. 3).

It is interesting to note that nowhere were there any iron-producing colonies formed only of bacteria without accompanying protozoa. The literature contains indications of the occurrence in soils of heterotrophic bacteria, which are capable of mineralizing organic iron. In the B horizon of a podzolic soil, for example, W. Grawford (21) discovered, in a group of corny-bacteria, a heterotrophic bacillus capable of separating mineral iron from iron citrate while using the latter as a source of carbon nutrients. On this basis he suggests that the bacteria may play a role in the secretion of iron in the B horizon.

The present author segregated 16 pure bacterial cultures which had grown together with the protozoa in the fulvate media. All of these turned out to be oligotrophic and capable of growing even on aqueous agar. When these were cultivated on fulvate gel, they apparently made no changes whatever in the organic-mineral complex and evidently used it only as a physical substratum. Without denying the possibility that some representatives of the order Mycobacteriales might have taken part, it must be stated that apparently the greatest importance in this process attaches to certain protozoa and actinomyces.

Microbes fostering the decomposition of fulvate complexes and sesquioxides were found in all the soil specimens at the author's disposal; this process was in all cases accompanied by the formation of iron concretions of one form or another. The most frequently encountered agents in this process were amoebae from the Limax group, followed by small

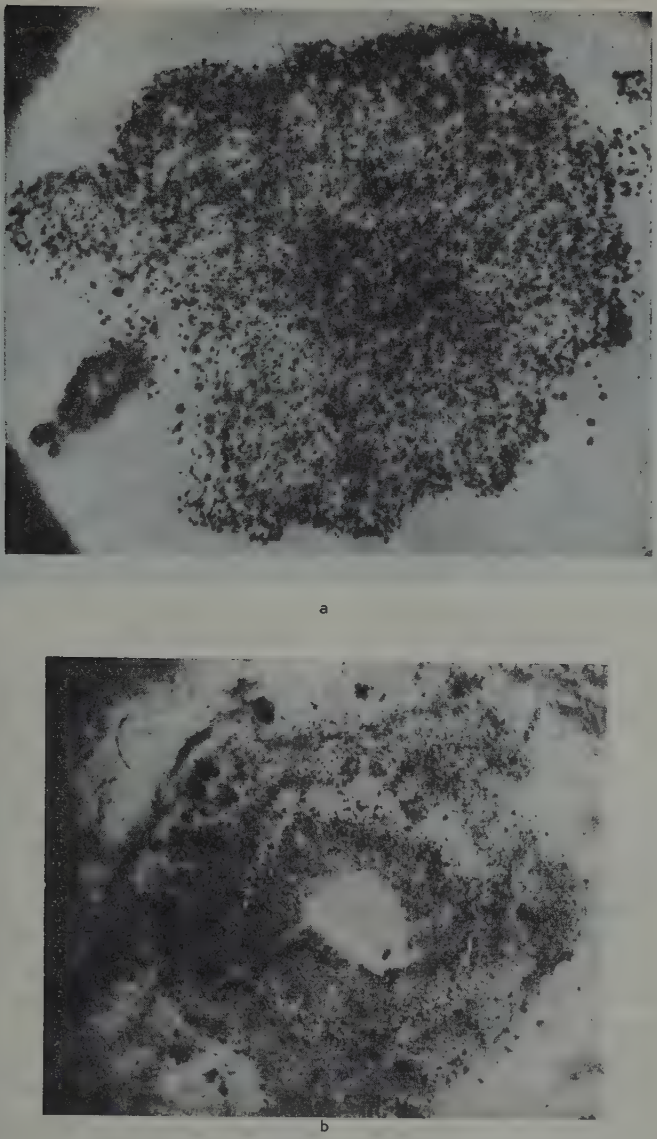

Fig. 3a and 3b. Overall views of accumulations of iron-filled cells of protozoa (magnification x 70).

flagellates and actinomyces in decreasing order of importance. One task of further investigation is to determine the species to which these belong.

The deposition of iron hydroxides by microorganisms must be considered to be a result of their destruction of the organic-mineral complex of fulvic acids and sesquioxides. The entire decomposition of the fulfic acids may be represented as follows. After the fulvate gel had been inoculated, a thin film of non-spore forming bacteria first developed on the surface of the gel; this was followed by multiplication of the protozoa which consumed the bacteria and the fulvic acid simultaneously. It is possible that the more available part of the complex, which was not bonded with iron, was consumed first and that the organic mineral bonds were broken only as the former source was exhausted.

In this process the organic part of the complex was used up and the iron, which is merely

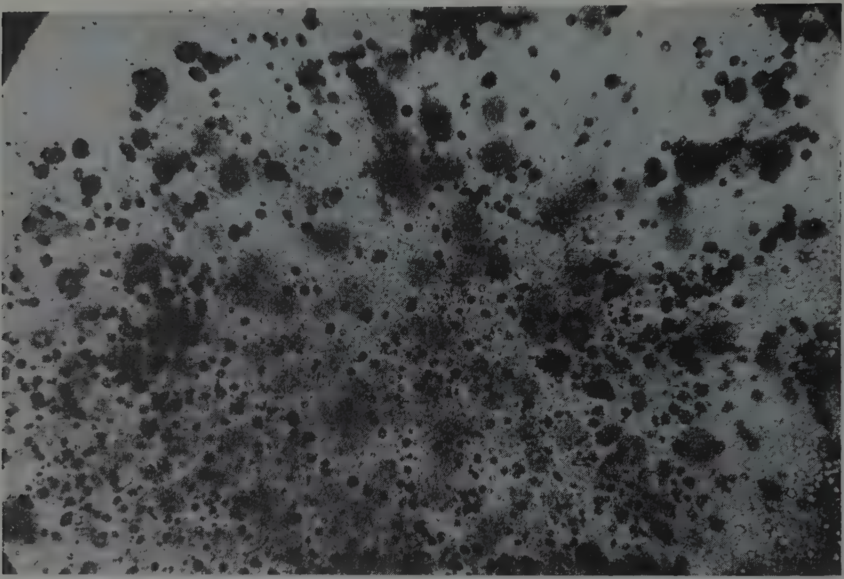

Fig. 3c. Individual cells of protozoa in various stages of becoming filled with iron (magnification x 140).

inert, was secreted as iron hydroxide, resulting in the formation of small iron concretions. The first stage in the process, which does not involve the liberation of iron hydroxides, takes place much more rapidly than the succeeding stages. Under the conditions of these experiments, the formation of iron concretions is not accompanied by complete mineralization of the fulvic acids. Observations were continued for approximately one year; during the course of this time no cases were observed in which the fulvate gel disappeared completely. It is possible that in nature this process takes place somewhat more rapidly. The liberation of mineral iron by the previously mentioned protozoa and actinomyces suggests that these microorganisms play a large role in the accumulation of mineral iron in the appropriate soil horizons.

It may be considered as established that the microorganisms decompose the organic mineral complexes of fulvic acids and sesquioxides and, in freeing mineral iron, aid in its accumulation. The role of the aluminum in the composition of these complexes still remains unknown. The question arises, first of all, as to whether there is an accumulation of aluminum oxide in mineral form similar to the creation of the iron concretions. A test using aluminum as a reagent to detect the presence of negligible amounts of aluminum was unable to discover any accumulation of this element during the decomposition of the organic-mineral complex. It is possible that the aluminum is more strongly bonded to the fulvic acids than is the iron. In addition, aluminum is doubtless more toxic than iron; this may be a hindrance to the accumulation of any considerable quantities of this element by living cells. Thus the question of whether there is a destruction of the organic-mineral bond between fulvic acids and aluminum still remains open. Is the role of the protozoa limited to the transformation of soil humus by the decomposition of fulvic acids alone, or do they also make use of other humus substances? The available data still suggest no answer to this question. Observations at the present time, however, indicate that gels of ulmic and humic acids provide an excellent medium for these organisms. In this case they would hardly attract only bacteria which have much more difficulty in living in these media than on many other organic substrata.[4]

The literature (7) indicates that the distribution of protozoa in the soil is closely associated with the distribution of humus, and that Rhizopoda are especially associated with the humus parts of the soil, which are the richest in the bacteria on which they feed. It must be assumed that this applies not only to the bacteria which compel the protozoa to concentrate in the humus particles, but to the humus itself, which they use as a physical substratum and as one source of nutrients. On this basis, it must be considered that the soil protozoa (at least certain of them) are an active member of the community of autochthonous microorganisms in the soil.

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[4] In particular, when the synthetic medium without the addition of fulvate or humate gel was used in inoculating the soil suspension, there was a considerably greater growth of bacterial flora than in the same medium with humus substances. Under these conditions, however, no protozoa were observed.

The data obtained by the author suggest that there is a need for a new evaluation of the role of protozoa in the transformation of soil substances and in the formation of soils. Since they take a direct and active part in the decomposition of the soil humus, they are of necessity an important link in the chain of organisms in the biological cycle.

CONCLUSIONS

1. A study was made of the decomposition by microorganisms of the organic-mineral complexes of fulvic acids and sesquioxides. The results of this study have shown that an active role is played in this process by certain soil protozoa, primarily amoebae and partly small flagellates and actinomyces.

2. In consuming the organic-mineral substance, the microorganisms secrete iron hydroxides as minute iron concretions. In nature this is probably the reason for the iron accumulation in specific soil horizons.

3. Aluminum in the decomposition of the organic mineral complexes is not accumulated in a free state; this suggests that it is more strongly bonded to the organic part of the complex.

4. The soil protozoa must be considered as an active part of the community of autochthonous microorganisms in the soil.

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THE MEADOW-STEPPE SOILS OF THE EASTERN TRANSBAYKAL

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The Transbaykal is a peculiar mountainous country located at the very center of the Eurasian continent. The position of the Transbaykal within the continent explains the predominance in this territory of dry snowless winters, high summer temperatures and a distinct maximum of precipitation in summer. The topography is typically composed of alternating mountain ridges which are usually not high but have distinct orographic features and of broad intermontane valleys. The contrast in the distribution of the vegetative cover is also noteworthy. The mountain ridges are covered with deciduous Siberian forest, whereas the intermontane valleys contain a predominance of steppe and dry steppe vegetation; as the latter rises along the slopes on the southern exposures of the ridges it frequently comes into direct contact with the Siberian forest on the northern slopes. The peculiar features in the conditions of soil formation in the Transbaykal consist in the very great variety of soil forming parent materials and in the ubiquitous distribution of seasonal or perennial frosts. The soils formed under such conditions, of course, will not only differ considerably from similar soils of the European territory of the USSR, but may also belong to new soil groups which have still not been studied. The heterogeneous and peculiar features of the soil in the Transbaykal have already pointed out in papers by Filatov (8) and Prasolov (6). Prasolov has suggested distinguishing a separate Transbaykal soil province. In recent years, the provincial peculiarities of the mountain Siberian forest soils of the Western and Central Transbaykal were studied in detail by Nogina (5) and Ufimtseva (7).

The data for this paper were obtained from soil investigations made under the direction of Nogina in 1956 in the Southeastern Transbaykal, in which peculiar soils temporarily called meadow-frozen soils were encountered and described. This tentative term will be used in this article.

Before characterizing meadow-frozen soils, it will be in order to describe briefly the conditions under which they are formed.

The region under consideration is bounded on the west and on the north by the Gazimur ridge and on the east by the Argun'ya River. The Kalga River may be considered as the southern boundary. Toward the northeast, the area is intersected by the Nerchinskiy and Klichkinskiy mountain ridges, whose absolute elevation is no more than 1500 meters above sea level. The lowlands between the ridges have a rolling topography. These hills have gentle slopes and dome-shaped peaks and are no more than 700 to 800 meters above sea level. The low hills are separated by broad, flat depressions. The relative height of the hills above the bottoms of the depressions is 200 to 300 meters. The main features of the present-day topography were found as early as Pre-Paleozoic times, when the Archean rocks were folded with a northeast trend and cut through by numerous intrusions in the same direction. This direction was retained for the most part by the numerous succeeding orogenic movements.

The Eastern Transbaykal was invaded by the sea three times -- in the Cambrian, in the Devonian, and at the beginning of the Mesozoic. In late Jurassic times the sea covered the entire territory; the retreat of the sea was accompanied by intensive tectonic activity and by extrusions of rocks along the lines of faults. At the beginning of the Cretaceous period an uplift began which reached its greatest intensity in Tertiary times, when it was accompanied by the extrusion of basalts.

The complex geologic history of this area is reflected in the great variety of its rocks. The mountain ridges are composed of Paleozoic and Pre-Paleozoic granitic rocks; the long low hills are made up of sandstones, conglomerates, shales, limestones, extrusive rocks and tuffs of Paleozoic and early Mesozoic age; Tertiary deposits -- conglomerates, sandstones, shales, sands and clays -- fill the depressions in the topography. In the Argun'ya area a chain of low hills is made up of basaltic extrusives of Tertiary age. The soil forming parent materials on their gentle rounded slopes are represented by fine deluvial-proluvial clay loams. The valleys and the broad lowlands are full of eluvial deposits which have primarily fine textures. The peaks and the steep slopes of the ridges and hills are covered by thin gravel eluvium and eluvial-deluvial matrix rocks.

The climate of the region under investigation is severe and sharply continental. The mean annual temperature ranges from -3.5 to 5° C. The average annual precipitation is 360-400 mm; in some years this varies from 280-580 mm. The winters are characterized by little snow and wind and by heavy frosts. The average annual temperature in January is -30° C. The blanket of snow is rarely more than 10 cm thick. The spring is short and dry with strong winds and continuous thawings. There are no spring floods, for the snow cover usually evaporates until temperatures above zero are reached, and the amount of precipitation in spring is neglibible. From the beginning of May daily temperature is usually above zero, but the morning frost may continue until the middle of June. The summer months, especially July and August, are the wettest. During these two months approximately 85% of the annual precipitation falls. The summers are fairly hot, the average temperature in July being above 20° C. The frost-free period continues on the average for about 100 days, varying in individual years from 70 to 140 days. The first frosts usually appear at the beginning of September. By the middle of October the average daily temperatures are again below zero. During the Autumn months -- September and October -- there is about 50 mm of precipitation.

The severe winters with little snow favor the deep freezing of the soil and the broad distribution of the perennial frosts. The large number of permanent and intermittent springs is due to the presence of a frozen horizon in the soil.

According to the nature of its vegetation, the meadow-frozen soil area is a peculiar forest-meadow zone similar to the forest-steppe zone of the European part of the Soviet Union in its position between the taiga with its sod (mountain) forest non-podzolized soils, and the steppes with their chernozem soils.

The northern slopes are covered with low birch or aspen mixed with willow, under which there are peculiar gray forest gley soils. The southern slopes are covered with low grass varieties and meadow-steppe grasses. These will be described in greater detail, since it is under these very meadow-steppes that frozen meadow soils are formed. The grass is usually three-story. The first story is made up of medicinal burnet (Sanguisorba officinalis, white peonies (Paeonia albifiora Pall.), medicinal valeriana (Valeriana officinalis L.) and Hamerócalis minor Mill. The second story shows a predominance of hare's ear (Bupleurum scorzanerifolium), vetch (Vicia unijuga A. Br.), blue meadow grass (Poa Botricides Trin.), koelaria (Koelaria gracilis Pers.), swollen-seed (Phlojodicarpus dohuricus), lupine clover (Trifolium lupinaster L.), etc. The third story consists of Poa Turzaninovi Kryl et Serg, Saussurea Amara L. D. C., Allyssuni biovulatum N. Busch, etc. There is also a considerable amount of Siberian tansy (Tanacetum sibiricum L.) among the grasses.

The depressions are usually swampy and overgrown with grass-sedges and sedge meadows.

The meadow-frozen soils are developed on the relatively broad watersheds and on the gentle southern slopes. They are formed on deluvial-proluvial thin clay loams and clays containing small amounts of gravel. These deposits frequently have heterogeneous textures. At a depth of about 2 meters the deposits are usually underlain by a series of rocks.

The humus horizon of the meadow-frozen soils is dark grey and friable, and has a well defined scaly structure. Its thickness, depending upon the amount of erosion and deposition, varies on the average from 10-60 m. The lower boundary of this horizon is tongue-shaped. Most of the humus comes in within the first meter, but individual tongues penetrate to a meter and a half or deeper. The formation of these tongues is associated with the penetration of the humus horizon into cracks in the frozen stratum of the soil. The humus horizon grades into a multicolored transitional horizon. At a depth of 70-80 m, the predominant color becomes dirty brown, and the soil becomes more compact with a nut-like structure. At the depth of 120-130 cm, the indications of gleying, which begin to appear immediately below the humus horizon, become very clear; they take the form of a rusty coloration, segregations and iron-manganese concretions. The soil gradually acquires the platy structure typical of horizons that have been frozen for a long time. A characteristic feature of the meadow-frozen soils is the presence in the profile of a frozen layer, and of a layer of water above this. At the beginning of summer the frozen layer may be encountered within the first half meter of depth; by the middle of August this drops to two meters. In the latter case the horizon of melt water above the frozen layer appears at a depth of 170-180 cm. The profile contains no discolored areas of easily soluble salts and carbonates. Krotovinas, which are so typical of the steppe soil profile, were not encountered in a single section.

Meadow-frozen soils have a very fine silty clay loam texture[1] (Table 1). The lutite fraction

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[1] The analyses were done by the present author and in the laboratory of the Department of Soil Geography and Mapping, V.V. Dokuchayev Soil Institute, Academy of Sciences, USSR, under the direction of V.F. Molchalova.

Table 1

Particle size analysis of meadow-frozen soils (N. A. Kachinskiy)[a]

Profile No.	Depth, cm	Solution loss in HC1	Particle diameters, mm						
			1.0— —0.25	0.25— —0.05	0.05— —0.01	0.01— —0.005	0.005— —0.001	<0.001	<0.01
71	0—20	1,09	11	11	23	8	14	31	53
	22—32	2,81	9	14	27	5	10	31	46
	40—50	2,63	10	10	29	6	11	31	48
	65—75	2,66	11	12	24	7	12	31	50
	90—100	1,65	12	13	23	6	11	33	50
	120—130	3,16	7	9	24	8	13	35	57
	150—160	1,51	10	11	24	7	11	36	56
	180—190	2,48	17	12	21	7	10	31	48
	225—235	2,49	16	11	19	7	12	33	52
201	0—10	4,32	5	15	25	9	14	28	51
	15—25	2,34	4	14	24	6	15	35	56
	30—40	3,36	2	9	26	9	15	36	60
	60—70	1,58	2	12	29	7	14	36	57
	100—110	2,06	5	11	29	8	15	38	61
	130—140	14,22	2	3	26	8	25	22	55

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[a] Analysis by S.K. Antropova and N.A. Kamennykh.

Note: Comma represents decimal point.

and the clay itself are fairly evenly distributed through the profile. The small increase in these fractions at the depth of 120-160 cm in profile 71 is apparently due to heterogeneous depsoits.

Table 2 shows the results of a structural analysis of the meadow-frozen soils. The humus horizon has a well-defined water-stable structure. The horizons below the humus horizon, in the dry condition, had a blocky structure. Water-stable structures are completely absent in these horizons.

Chemical data of meadow-frozen soils are shown in Table 3. Their humus content is very high, reaching 8-12% in the upper horizons. The carbon nitrogen ratio, which varies around 13 is typical of the forest-steppe soils of the European part of the USSR. The ratio of humic acids to fulvic acids in the upper horizons is 2. 6 (Table 4); with depth it decreases to 1. 3. Within the humic acids, the predominant fractions are those associated with calcium and with the mineral part of the soil. The absorption capacity of the humus horizon reaches 40-45 meq per 100 g of soil. The content of adsorbed cations gradually decreases with depth. The increase in the adsorption capacity in the middle part of the profile is due to differences in texture. The comparatively high adsorption capacity is the result of the fine texture of the soil and the large humus content. Calcium is predominant among the adsorbed cations; the amount of magnesium ranges from 8-29% of the absorption capacity. The content of adsorbed hydrogen and aluminum is negligible, not exceeding 2% even in the most acidic horizons. It is interesting to note that there is a relatively high content of adsorbed manganese (1 meq per 100 g of soil in the humus horizon and up to 3 meq in the horizons which show indications of gleying). The reaction of water suspension is close to neutral in the humus horizon, acidic in the middle part of the profile and slightly acid in the lower part. The reaction in the salt suspension is acidic throughout the entire profile and strongly acidic at a depth of 30-80 cm (pH is 4. 0-4. 5). This depth also has the greatest exchange and hydrolytic acidity, although the absolute magnitude is very small. There is very little change in the total content of the elements throughout the profile (Table 5). Biological accumulation of phosphorus, sulphur and calcium have been observed in the upper horizons. In the gleyed horizons there is an increase in the content of manganese. The amount of sesquioxides scarecely changes throughout the profile. No indications of an illuvial process have been found in the distribution of mobile iron and aluminum, as determined in the Tamm's extract (Table 6), although the absolute content of these elements is fairly high (up to 500 mg per 100 g of soil). A characteristic feature of the meadow-frozen soils, which distinguishes them from the steppe and the meadow-steppe soils, is the absence of carbonates in the profile. As shown in the paper

Table 2

Structural composition of meadow-frozen soils (Profile 71) as percentages

Dry Sieving

Depth, cm	Particle diameter, mm			
	>10	10–1	1–0.25	<0.25
0–20	25	69	5	1
40–50	54	40	5	1
65–75	40	43	13	4

Wet Sieving

Depth, cm	Particle diameter, mm											
	>3			3–2			2–1					
	total	rock	fine earth	total	rock	fine earth	total	rock	fine earth	total	rock	fine earth
0–20	14.2	8.5	5.7	6.7	4.3	2.4	14.1	4.5	9.6	16.2	22.7	16.1
40–50	8.9	8.9	—	5.5	5.5	—	6.1	5.3	0.8	4.9[a]	20.8[a]	51.8
65–75	11.7	11.7	—	2.6	2.6	—	5.8	5.1	0.7	6.7[a]	20.3[a]	52.9

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[a] These fractions are almost entirely composed of sand.

by Afanas'yeva (1), the carbonate profile in the steppe and forest-steppe soils depends on the ratio between the upward and downward movement of soil solutions and the content of CO_2 in them. The alkalinity of the profile in the meadow-frozen soils is due to the peculiar water regime in them, which is associated with the nature of the precipitation and with the frosts. In the spring and the first half of summer, the upward moisture movements are confined to a thin active soil horizon, whereas in the second half of summer, when the soil thaws out to a depth of a meter and a half, the rainfall produces downward moisture movement in the soil. The leaching of the carbonates is facilitated by the high concentration of carbon dioxide in the soil solution during the second half of the summer; this is associated with the maximum of biological activity in the soil during this period and the low temperatures of the horizons above the frozen layer. In the middle of August the ground waters, which have a mineral content no greater than 0.3 g/l, contain almost exclusively calcium and magnesium bicarbonates. Because of the dissected topography, the carbonates are carried by moisture flow within the soil along the frozen layer into the valleys and the rivers.

In regard to agricultural production, the meadow-frozen soils are superior to the steppe soils of the Transbaykal. They have good water-stable aggregates in the humus horizon, and a high content of available calcium and nitrogen (Table 7). The low content of available phosphorous is evidently due to the fact that the phosphorous is for the most part bonded to manganese aluminum and iron; it is possible that in these soils the use of phosphorous fertilizers will not produce positive results without preliminary liming. But the chief peculiarity of meadow-frozen soils is their water regime. Throughout the entire area of the Transbaykal, the main problem in agriculture is moisture, especially during the dry spring. There is scarcely any aridity, however, in the meadow-frozen soil area, since in the dry season the vegetation draws on the water lying above the frozen layer. It is, therefore, hardly surprising that in the Chitinskiy oblast' it is this area that has the highest and most dependable harvest of grain and vegetable crops. There are, however, a number of problems in agriculture: the short vegetative period, the presence of late spring and early fall frosts, the late planting and the difficulty in plowing the soil before the planting because of the closeness of the melt water and the frosts, the soaking and beating down of the crops during the rainy period, and the large amount of erosion. Thus primary importance must be attached to certain measures, such as the correct selection of crops, the production of local early maturing and frost-resistant varieties, the proper selection of planting areas, measures to remove excess rain and melt water and to increase the soil temperature, and measures against erosion (contour plowing, protective belts, etc.).

In order to place the meadow-frozen soils

Table 3

The physical and chemical properties of meadow-frozen soils[a]

Profile No.	Depth, cm	Hygroscopic moisture, %	pH		Humus, % (after Tyurin)	Nitrogen, % (after Kjeldahl)	C:N	Cation adsorption, meq/100 g of soil (Gedroits)					Saturation, %	Adsorbed Mn, meq/100 g of soil	Adsorption capacity, meq/100 g of soil	Hydrolytic acidity, meq/100 g of soil	Exchange acidity in meq/100 g of soil (Sokolov)	
			water	salt				Ca	Mg	Na	H	total					H	Al
71	0—20	3,89	6,8	5,3	7,9	0,34	13	34,1	11,3	traces	0,2	45,5	0,4	1	38,7	1,2	0,06	none
	22—32	3,39	6,4	5,2	2,2	—	—	18,3	9,0	"	0,1	27,4	0,4	traces	25,6	1,0	0,06	"
	40—50	3,29	6,2	5,0	1,1	0,05	13	15,8	8,3	"	0,2	24,3	0,8	"	24,0	1,2	0,04	"
	65—75	3,22	5,6	4,7	0,9	—	—	16,5	8,3	"	0,2	25,0	0,8	2	24,1	1,7	0,03	0,04
	90—100	3,36	6,2	4,3	—	—	—	17,6	9,0	"	0,2	26,8	0,7	2	25,4	1,7	0,09	0,02
	120—130	3,67	6,4	4,9	0,7	—	—	20,1	9,3	"	0,1	29,5	0,3	0,5	28,4	1,2	0,06	none
	150—160	3,61	6,5	5,4	0,8	—	—	23,6	9,0	"	0,1	34,6	0,3	1	28,7	1,2	0,04	"
	180—190	3,36	6,6	5,5	0,6	—	—	19,7	7,2	"	0,1	27,0	0,4	1	24,4	0,9	0,04	"
	225—235	3,21	6,8	5,3	0,8	—	—	20,0	6,1	"	0,1	26,2	0,4	3	24,4	0,9	0,04	"
201	0—10	4,39	6,7	5,5	12,0	0,54	13	42,3	9,0	—	0,2	51,6	0,4	—	45,3	1,6	—	—
	15—25	4,23	6,2	5,0	5,7	0,25	13	33,2	8,7	—	0,2	42,6	0,5	—	38,2	2,6	—	—
	30—40	3,89	5,3	4,4	2,4	0,09	13	23,5	7,6	—	0,6	31,6	2	—	31,9	3,2	—	—
	60—70	3,96	5,1	4,0	1,3	—	—	24,6	4,8	—	0,4	29,9	1,3	—	30,3	2,7	—	—
	100—110	4,32	5,8	5,1	—	—	—	31,9	4,3	—	0,2	36,4	0,6	—	31,3	2,3	—	—

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[a] Analyses by N.A. Andreyeva, S.K. Antropova, L.A. Bulyayeva, Z.S. Karayeva, G.G. Rusakova and S.P. Ellin.

Note: Comma represents decimal point.

Table 4

Group composition of the humus in meadow-frozen soils (Profile 71), as percentages of the soil's weight (numerator) and of the total content of humus (denominator)

Depth, cm	Total humus content, %	Humic acids				Fulvic acids				Direct H_2SO_4 extract	Hot H_2SO_4 extract	Unhydrolized residue	Ratio of humic to fulvic acids
		O	I	II	total	O	I	II	total				
0—20	6,5	$\frac{0,6}{9,2}$	$\frac{1,1}{17,6}$	$\frac{1,2}{17,9}$	$\frac{2,9}{44,6}$	$\frac{0,6}{9,0}$	$\frac{0,4}{6,5}$	$\frac{0,1}{1,5}$	$\frac{1,1}{16,5}$	$\frac{0,3}{4,3}$	$\frac{0,7}{11,0}$	$\frac{1,8}{23,1}$	2,6
22—32	1,8	$\frac{0,2}{0,6}$	$\frac{0,2}{11,2}$	$\frac{0,5}{25,1}$	$\frac{0,9}{47,4}$	$\frac{0,2}{8,4}$	$\frac{0,4}{21,3}$	$\frac{0,05}{2,8}$	$\frac{0,6}{32,4}$	$\frac{0,1}{6,7}$	$\frac{0,3}{19,0}$	$\frac{0,06}{3,4}$	1,5
40—50	1,0	$\frac{0,1}{11,0}$	$\frac{0,07}{7,0}$	$\frac{0,3}{30,0}$	$\frac{0,5}{50,0}$	$\frac{0,04}{4,0}$	$\frac{0,3}{30,0}$	$\frac{0,02}{2,0}$	$\frac{0,35}{35,0}$	$\frac{0,1}{11,0}$	$\frac{0,1}{10,0}$	$\frac{0,06}{6,0}$	1,3

Note: Comma represents decimal point.

Table 5

Total chemical analysis of meadow-frozen soil (Profile 71), in percentages of ignited soil

Depth, cm	Ignition loss, %	SiO_2	R_2O_3	Fe_2O_3	Al_2O_2	P_2O_5	CaO	MgO	MnO	SO_3
0—20	16,69	68,98	23,18	5,26	17,92	0,24	0,86	1,37	0,06	0,55
20—30	9,27	69,58	24,12	5,59	18,53	0,15	0,69	1,36	0,06	0,48
40—50	7,82	69,34	23,44	5,72	17,72	0,15	0,68	1,21	0,07	0,47
65—75	8,28	69,39	24,50	5,23	19,27	0,18	0,70	1,08	0,11	0,36
120—130	8,99	67,35	26,40	4,25	22,15	0,22	0,84	1,64	0,15	0,48
180—190	7,68	69,22	24,37	5,62	18,75	0,21	0,89	1,51	0,15	0,48
225—235	8,12	68,83	25,30	6,22	19,08	0,19	0,77	1,31	0,13	0,29

Note: Comma represents decimal point.

within the present-day soil classification, they will be compared with the soil of the adjacent territories. In the west, in the Nerchinskaya valley, Ufimtseva has described some meadow-chernozem frozen soils that are morphologically similar to the meadow-frozen soils, but differ from them in that they contain carbonates in the soil profile. This distinction is probably due to the smaller amount of frosts, the higher temperatures and the smaller amount of precipitation. Because of the lack of analytical data on these soils, it is impossible to make a detailed comparison with the meadow-frozen soils and to come to any definite conclusion.

In the east, within the Zeysko-Bureynskaya lowland, the meadow vegetation grows on a soil which has been described by Liverovskiy and Rubtsova (3) as a dark-colored meadow soil. The thick dark-colored meadow soils and the meadow-frozen soils are close to each other in their morphological appearance, the amount and the nature of the humus, the reaction in the soil profile, the properties of the soil adsorptive complex, in the absence of easily soluble salts and carbonates in the profile, and in the total chemical analysis.

In contrast to the meadow frozen soils, however, the meadow dark-colored soils are developed under the conditions of a flat topography and a more humid and warm climate. They are characterized by the presence of relict (or present-day) indications of solodization (podzolization) and a somewhat higher amount of gleying in the soil profile. Thus the classification of the dark colored meadow soils is still under discussion.

In our opinion, the meadow-frozen soils

Table 6

Contents of SiO_2, Fe_2O_3 and Al_2O_3 in the Tamm's extract, mg/100 g of soil[a]

Profile No.	Depth, cm	SiO_2	Fe_2O_3	Al_2O_3
71	0—20	140	490	470
	22—32	160	320	320
	40—50	90	400	360
	65—75	110	460	410
	90—100	120	380	350
	120—130	210	440	350
	150—160	90	370	400
	180—190	110	320	310
	225—235	120	390	340
201	0—10	100	510	470
	15—25	110	480	510
	30—40	90	360	400
	60—70	30	280	360
	100—110	150	220	360

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[a] Analysis by N.A. Andreyeva.

Table 7

Content of available nutrients, mg/100 g of soil

Profile No.	Depth, cm	P_2O_5 after Kirsanov	P_2O_5 after Chirikov	K_2O (after Maslova)	N (after Tyrin and Kononova)
71	2—20	2.5	2.2	41.2	13.1
	22—32	0.6	0.5	17.8	4.5
201	0—10	3.1	2.8	72.6	24.9
	15—25	0.7	0.5	19.5	11.8

cannot be assigned to any of the existing soil groups and must be distinguished as an independent soil group.

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METHODS

THE USE OF SOME INDICES OF THE SOIL'S LIMING REQUIREMENT AND THE INTERRELATIONSHIP BETWEEN THEM

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At the present time, the soil's liming requirements and the amounts of lime (even within small soil areas such as the Lithuanian SSR) are determined by the use of nonuniform indices of the soil properties, most of which are unsuitable for large-scale determinations.

This paper is based on a study of the conditions under which the complex indices of the soil's liming requirements might be replaced by simpler indices which are quicker and more useful in mass determinations. A study was made of the interrelationships between the pH in the salt extract, the exchange acidity (and the mobile aluminum), the hydrolytic acidity and the degree of saturation with bases in the soils of two zones in the Lithuanian SSR: the Zhemaitis (western) zone and the Vilnius (eastern) zone. Almost all the soils of the Republic which require liming are concentrated in these two zones. The following methods were used in the investigation: a) gradual removal of H^+ with various salts by the method of successive treatments, b) studies of the changes in the soil properties after liming with various amounts, c) correlation of the data on the lime effectiveness with the data on soil properties, and d) a statistical comparison of the acid indices in a number of acid soil samples in the Republic.

It was established that for the majority of soils of the Lithuanian SSR which require liming, the magnitude of the saturation with bases -- V -- is closely correlated with the pH of the salt extract -- $pH_{(KCl)}$. In the case of the plowed acid sod-podzolic coarse and medium clay loam[1] and sandy loam soils, it was determined that there is a linear relationship between V and $pH_{(KCl)}$ (Fig. 1), expressed by the equation:

$$pH_{(KCl)} = 0.016V + 3.9. \qquad (1)$$

Equation 1 is not always suitable for newly cultivated and sod-podzolic gley soils which contain excess moisture, but after these soils have been drained, this equation may be applied.

It was interesting to check the applicability of Eq. 1 by a comparison with data on the sod-podzolic soils of other Republics. Figure 1 shows the results of investigations of certain soils of the European part of the non-chernozem belt of the USSR, as taken from papers by Kedrov-Zikhman (4), Alyamovskiy (2), and Shcherba (8); these show that in the case of coarse and medium clay loams and sandy loams there is almost a linear correlation. For the same $pH_{(KCl)}$, in the case of fine clay loams the magnitude of V is higher and in the case of sandy soils lower.

In using the values of V as computed by Kedrov-Zikhman (4) from the experimentally determined magnitude of the full hydrolytic acidity, it was found that in the majority of cases the above relationship applies to soils with any texture (Fig. 1).

The relationship in equation 1 applies to pH values between 4.0 and 5.0 and is especially close for those between 4.2 and 4.7.

In the case of the limed soils of the Lithuanian SSR (coarse and medium clay loams and sandy loams) the relationship between $pH_{(KCl)}$ and V, in the range between the pH of 4.7 and the pH of 6.0, is expressed by Equation 2 (Fig. 2):

$$pH_{(KCl)} = 0.034V + 3.0. \qquad (2)$$

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[1] Almost no acid fine clay loams and clays are found in the Lithuanian SSR.

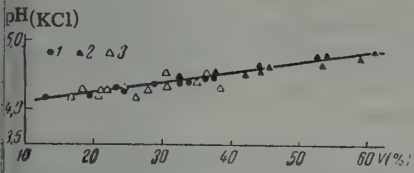

Fig. 1. Relationship between $pH_{(KCl)}$ and V for acid soils.

Soils of the Lithuanian SSR:
1 - coarse (and medium) clay loam;
2 - sandy loam;
3 - sandy loam soils of other oblasts in the European part of the USSR (according to data from various authors).

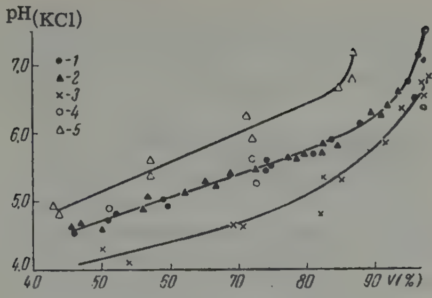

Fig. 2. Relationship between $pH_{(KCl)}$ and V for limed soils.

Soils of the Lithuanian SSR:
1 - coarse clay loam;
2 - sandy loam.
Soils of other areas in the European part of the USSR, after O.K. Kedrov-Zikhman;
3 - fine clay loam;
4 - medium clay loam;
5 - sandy loam.

In the case of a $pH_{(KCl)}$ of 6.0 or more, the elationship between $pH_{(KCl)}$ and V for limed oils is expressed by the Peach and Bradfield 10) equation:

$$pH_{(KCl)} = C + \log (S/H_H),$$

here S is the total absorbed bases, H_H is the ydrolytic acidity, and C is a constant of 5.30 o 5.40.

The same curve (Fig. 2) applies to limed oils according to the data from Kedrov-ikhman (4); although the medium clay loams re closer to the previously mentioned Eq. 2, e fine clay loams have a higher V and the andy loams a lower V for the same $pH_{(KCl)}$. or the soils of the Lithuanian SSR, both non-med and limed, the relationship between $H_{(H_2O)}$ and V up to a pH of 6.0 is expressed y the single linear equation:

$$pH_{(H_2O)} = 0.03V + 4.1. \qquad (3)$$

Equation 3 is similar to that of Manschard 9), which was derived for the soils of ermany -- $pH_{(H_2O)} = 0.0345V + 4.0$ -- and lso to that of Muñoz Tobadela and [Gutian yyey] (7), derived for the soils of Spain -- $H_{(H_2O)} = 0.0345V + 3.8$. Thus there exists a airly constant relationship between the pH and e degree of saturation with bases for the soils f various areas in the non-chernozem belt of urope.

In establishing the liming requirements of oils, there is no need to determine the quantity f mobile aluminum along with the exchange acidity. It is well known that in the KCl and NaCl extracts from acid soils, the amount of mobile aluminum is almost equal to the magnitude of the exchange acidity (3). In the $CaCl_2$ extract, the amount of mobile aluminum is approximately 55 to 75% of the exchange acidity.

An experiment was conducted to determine the titration acidity and the amount of Al^{+++} by Sokolov's method (6) in 1.0 N solutions of KCl, NaCl, and $CaCl_2$, in which there were equal amounts of $AlCl_3$; in the first two cases there was complete equality between both the quantities determined, whereas in the $CaCl_2$ solution the content of aluminum was only 56 to 57% of the acidity -- that is, virtually the same as that determined in the $CaCl_2$ extract from the soil (Table 1).

Thus the smaller amount of mobile aluminum in the $CaCl_2$ soil extract was due to the method of determination.

The three indicators of the soil's acidity are essential in determining the soil's liming requirements: the $pH_{(KCl)}$, the exchange and the hydrolytic acidities -- H_E and H_H.

Investigations of acid sod-podzolic plowed soils of the Republic, which are similar in qualitative composition but differ in texture and in the degree of podzolization, have shown that under the same pH conditions, the relationship between the exchange and the hydrolytic acidities is a fairly constant quantity. For a $pH_{(KCl)}$ from 4.0 to 5.0, which is typical of soils requiring liming, this ratio is approximately a straight-line function $C_H +$ (Fig. 3).

Table 1

The effect of various solutions on the precipitation of aluminum by sodium fluoride

Solution	Acidity, ml of 0.01 N NaOH per 25 ml of solution		
	Without NaF	With NaF	Amount of Al^{+++}
KCl	29.00	0.05	28.95
	28.80	0.00	28.80
NaCl	28.80	0.00	28.80
	28.80	0.00	28.80
$CaCl_2$	28.40	12.20	16.20
	28.50	12.50	16.00

The analytical expression of the linear relationship is as follows:

$$100\ C_{H^+} = 0.145(H_E\ 100/H_H) + 0.35, \quad (4)$$

where C_{H^+} is the antilogarithm of the pH, H_E is the exchange acidity, and H_H is the hydrolytic acidity (without multiplication by the coefficient 1.75). The terms are multiplied by 100 in order to simplify the calculations.

The linear relationship between $\log(H_H/H_E)$ and the pH also holds true in determining the exchange and the hydrolytic acidity by means of salts with the same cations, for example for the ratios

$$\frac{H_{CaCl_2}}{H_{Ca(OOCCH_3)_2}}, \quad \frac{H_{NaCl}}{H_{NaOOCCH_3}},$$

and to a lesser degree for

$$\frac{H_{KCl}}{H_{KOOCCH_3}}.$$

The initial ordinate and the slope of the line, however, will be different for each salt.

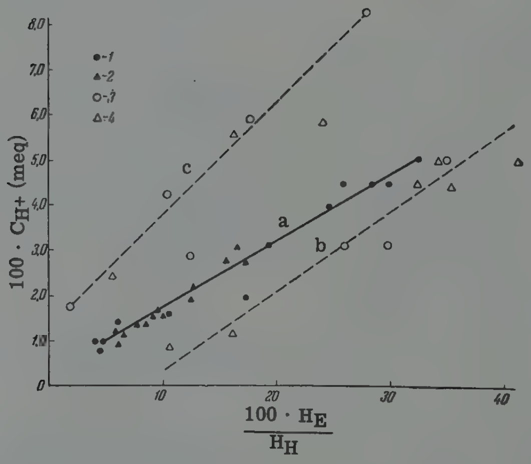

Fig. 3. Interrelationship between C_{H^+} and the exchange-to-hydrolytic acidity ratio.

Soils of the Lithuanian SSR:
1 - coarse (and medium) clay loam; 2 - sandy loam.
Soils of other areas in the European part of the USSR (according to data from various authors);
3 - clay loam; 4 - sandy loam.

a - soils of the Lithuanian SSR, according to M.M. Katsas and G.I. Rozovskis;
b - according to N.I. Alyamovskiy;
c - according to L.I. Korableva and S.V. Shcherba.

Equation 4 applies to the same soils as quation 1, and may be used in investigating e liming requirements of the main varieties cultivated soils in the Republic. This em- rical relationship makes it possible to deter- ine tentatively the magnitude of the exchange idity by the hydrolytic acidity and vice versa. ie relationship may also be used as a control mass-production analysis.

Comparison of the magnitudes of the ex- ange and the hydrolytic acidity according to ita from Alyamovskiy (2) Korableva (5) and icherba (8) also indicates a linear relation- iip between C_{H^+} and H_E/H_H; as can be seen om Fig. 3, however, the slope of the line r this relationship differs among the various vestigators. It is possible that if the same ethods had been used in determining the agnitudes of H_E and H_H, the slope of the ies according to the data from the individual vestigators would also have been the same. should be noted that, according to the data om these authors, the logarithmic equation ay also be applied to soils having various xtures, from sandy loam to fine clay loam.

The form of Equation 4 reflects a sharp in- rease in the exchange acidity and a decrease the pH, with a comparatively small change the hydrolytic acidity.

This is also confirmed in the successive emoval of H+ from the soil by salt solutions id by liming the soils with various amounts of rtilizers. In the pH$_{(KCl)}$ range from 4.5 4.0, even when there is a small increase the pH, a sharp drop is observed in the xchange acidity; when the pH$_{(KCl)}$ is some- hat higher (4.6 to 5.0), the drop in the exchange acidity is somewhat less sharp, and in the case of a weakly acidic reaction, the exchange acidity is already so small in absolute magnitude that its change as the pH$_{(KCl)}$ increases is scarcely noticeable (Fig. 4).

The great differences in the magnitudes of the ratio between the exchange and the hydrolytic acidities, which are associated with small variations in the values of the pH$_{(KCl)}$ of the soils in the Republic, will have considerable influence on the varying effectiveness of liming of these soils (Table 2).

In view of the sharp rise in the exchange acidity with the decrease in the pH, and the great increase in the ratio between the exchange acidity and the hydrolytic acidity and the resulting greater effectiveness of liming, it would be expedient in calculating the amount of lime to segregate the strongly acid and medium acid soils into a separate sub-group. This should be kept in mind in calculating the lime requirement according to the pH$_{(KCl)}$ and the soil texture, being guided by the Table suggested by Alyamovskiy (1). In addition, since the acid soils of the Lithuanian SSR are predominantly coarse clay loam, sandy loam and sandy, the lime requirement for the coarser soils must be more strongly differentiated than is seen in Table 3.

The optimal amounts of lime fertilizers, as determined by the pH$_{(KCl)}$ of the soil and its texture, have been established by correlating the data from field and laboratory investigations. These correspond to the optimal amounts of lime according to the hydrolytic acidity: 0.5 of the norm for sandy and sandy loams and 0.75 of the norm for clay loams.

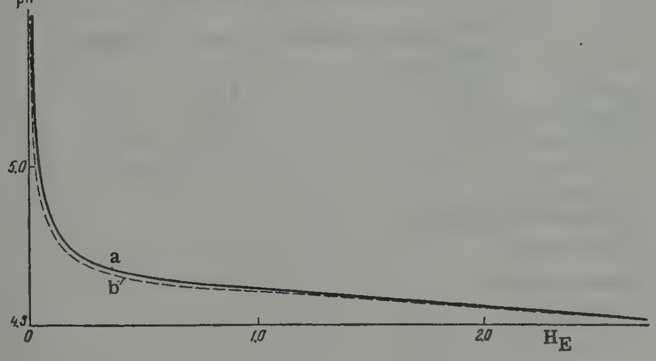

Fig. 4. Relationship between the pH$_{(KCl)}$ and the exchange acidity:

a - exchange acidity; b - mobile aluminum.

Table 2

Effectiveness of liming of soils of the Lithuanian SSR with various degrees of acidity

Soil and Locality	pH (KCl)	$\frac{H_E}{H_H}$ %	Optimal amt. of lime, metric tons/ha	Incr. in yield in crop rotation resulting from liming, cntr/ha		Remarks
				from 1 metric ton $CaCO_3$	maximum, cntr/ha	
1. Sod-strongly podzolic coarse clay loam soil on boulder clay loam (Zhemaytiyskaya zone, Samalishskaya experimental station)	4.3	31.5	4.0—7.0	13.42	100.23	after 7 years
2. Sod-medium podzolic gley sandy loam soil on clay loam (northern part of the eastern zone, El'mininkskaya experimental station)	4.5	19.0	1.5—3.0	7.29	43.55	after 6 years
3. Sod-medium podzolic sandy loam soil on gravel (eastern zone, Boke experimental agricultural station)	4.6	14.5	1.5—2.5	4.51	11.89	after 4 years

Table 3

Amounts of lime fertilizer (in metric ton/ha)

Soil category, according to texture	Extremely acid	Strongly acid	Medium acid		Slightly acid
	pH$_{(KCl)}$ of soil				
	$\leqslant 4.2$	4.3-4.5	4.3-4.5	4.9-5.0	5.1-5.5
	Content of mobile aluminum				
	Very high	High	Medium	Low	Traces
Sandy	4^a	3^a	2^b	1.5^c	0—1
Sandy loam	6^a	4^a	3^a	2.5^b	$1—2^c$
Clay loam	8^a	6^a	5^a	4.0^b	$2—3^c$

Soils requiring liming:

[a] first order;

[b] second order;

[c] third order.

CONCLUSIONS

1. In determining the soil's liming require-
ent, the following indices are significant:
e $pH_{(KCl)}$ as an index of the liming require-
ent, the exchange acidity as an index of the
gree of this requirement, and the hydrolytic
idity, which is usually used for a more
curate determination of the amount of lime.
hen data on the $pH_{(KCl)}$ are available, there
no need in determining the liming require-
ents of plowed soils to combine the indices
th the soil's saturation with bases.

2. On the basis of the relationship between
e $pH_{(KCl)}$ and the forms of the potential
idity, in determining the amounts of lime
cording to the $pH_{(KCl)}$ and the soil texture,
e must divide the medium and strongly acid
ils into sub-groups, increasing the amounts
lime for the more strongly acid soils.

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EFFECT OF FUNCTIONAL SOIL MOISTURE PROPERTIES ON THE RATE OF MOISTURE UPTAKE BY WOODY PLANTS

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At the present time the laws governing the utilization of soil moisture by plants have come under special scientific discipline, which is concerned with the water regime of plants and soil. This has occurred through the combination of three sciences: plant physiology, soil physics and meteorology. Much more work, however, is required in the study of these laws before this task may be considered completed.

There has been almost no quantitative consideration of such extremely important problems as moisture movement toward the roots in soils possessing different physical properties, the physiological reactions of plants to changes in the soil moisture properties, which take place when the soil moisture level is lowered, and the effect of the soil-water regime on the growth and development of plants.

The difficulties in the study of these problems are due to their complex nature, so that there must be close agreement in the methods used in all the investigations made by plant physiologists, soil scientists and meteorologists. Unfortunately, specialists have thus far made little use of the achievements of related sciences in their work on these problems. In particular, physiologists studying the water regime of plants under natural conditions almost never make any use of the physiological condition of various parts of the root systems, which determine the potential absorption of moisture from the soil. Soil Scientists, in turn, in studying the water regime in soils, do not describe in sufficient detail the functional properties of the soil moisture, even though these properties determine the moisture availability to plants.

The present article considers the little studied problem of the effect of the functional soil moisture properties on the intensity of its absorption by woody plants -- in other words, on its availability to plants.

The study of this problem has a long history. It began with a qualitative distinction of categories of soil moisture according to the degree of their availability to plants. The classic papers by Briggs and Shantz showed that there is a fixed boundary between available and non-available moisture to plants. It was considered that this boundary coincides with that between free and fixed moisture. This opinion has been maintained up to the present time by some investigators, such as Veihmeyer (15). The most recent work, however, has shown that the depressed growth of the plants is noticeable when the soil is lowered to the level of the "wilting moisture." Additional constants had to be introduced; "the critical moisture" (7), "the lower limit of the optimum soil moisture" (3, 8), "the first point of permanent wilting" (13), etc. These points were respectively associated with the boundary between loosely bonded and firmly bonded moisture.

The latest and most thorough works (9) have shown that even such generally accepted constants as "wilting moisture" are in essence not strictly defined; their magnitudes will vary depending on the type, the age, and the developmental stage of plants, the meteorological conditions and other factors. In recent investigations it has been shown that a gradual decrease in the soil moisture availability to plants takes place within quite a broad moisture range.

In addition, soil physics, on the basis of physical chemistry, has shown that the transition from one "form" of soil moisture to another takes place so gradually that up to now the problem has not been to find more accurate methods of determining the soil-hydraulic constant, but to carry out large scale quantitative investigations of the functional soil moisture properties, including above all the "negative (capillary) pressure" of the soil moisture and the "coefficient of moisture conductivity of the soil" (1). This has caused a great need for strict quantitative investigations of the relationship between the rate of soil moisture use, which serves as a measure of its availability, and the functional moisture properties.

Interesting results were obtained by Dolgov l), Kilyasev (5), and certain foreign investigaors, who noted that there is a direct relationhip between the rate of moisture use by plants, he negative pressure of the soil moisture, and s movement. The essence of the processes hich take place in the soil during the moisture dsorption, however, was not discovered and nalyzed quantitatively, so that some investigaors could assign a decisive role in the decrease f available moisture to a decrease in the negaive pressure (2, 16, 17) and others to a derease in the moisture movement (1, 11, 12, 4).

Thus the immediate goal of the present artile is to make a quantitative analysis of the rocess of absorption of soil moisture by the oots of woody plants.[1]

The following facts were taken into account developing the methods for this investigation.

The rate of moisture uptake by plants is xpressed by the formula:

$$Q = q\cdot S \ \left[\frac{cm^3}{sec}\right], \qquad (1)$$

here $q \left[\frac{cm^3}{sec}\right]$ is the rate of moisture flux toard the absorptive roots, and $S\,[cm^2]$ is the rea of the absorptive surface area of the root ystem.

However great the area of the absorptive urface, it is nevertheless many times smaller han the specific surface area of the soil, so hat the rate of moisture movement has a decive effect on the absorption rate.

The water flux toward the absorptive surface f an individual root increases under the effect f a cylindrical field of negative pressure of he moisture. Considering the nature of this lux in the plane perpendicular to the axis of he cylinder, one may, by analogy with the ydrodynamics equations, write

$$q = v\cdot f(R) \ \left[\frac{cm}{sec}\right], \qquad (2)$$

here $v \left[\frac{cm}{sec}\right]$ is the flat component of the flux nd $f(R)$ is the radial factor, which is a dimenionless quantity.

At this stage of the investigation, it was ecessary to limit the study to the flat componnt of the flux, which again by analogy with hyrodynamics may be represented as

$$v = -K\cdot I \ \left[\frac{cm}{sec}\right], \qquad (3)$$

where $v \left[\frac{cm}{sec}\right]$ is the flux rate, $I = \left[\frac{dH}{dl}\right] \frac{barye}{cm}$ is the negative pressure gradient of the soil moisture and $K \left[\frac{cm^3\cdot sec}{g}\right]$ is the coefficient of moisture conductivity of the soil.

All the parameters of the flux in this equation are expressed in the CGS units.

Analysis of moisture absorption includes empirical determinations of v, K and I as constant functions of the soil moisture. The accuracy of the results was checked by making calculations according to equation 3.

This method of analysis enables one to make a fair evaluation of the effect of the various functional properties of the soil moisture on the moisture availability to plants.

The multiplication of many factors under natural conditions creates such a complex picture that it frequently cannot be analyzed. In the first experiment, therefore, the attempt was made deliberately to conduct the experiments with the most simple natural objects. Accordingly, the investigations were made on a medium clay loam ordinary chernozem. Young oak plantations from the Derkul'skaya Forestry Experimental Station of the Voroshilovgrad oblast' were chosen for the study.

Since the original data for all the calculations were the data on the moisture of the soil and on the negative pressure of the soil moisture, the investigations began with a study of the relationship between these. Because of the phenomenon of hysteresis, this relationship was never uniform, although this experiment was concerned only with the branch of hysteresis loop.

In order to determine the desired relationship throughout the entire range of moisture available to the plants, it was necessary to use somewhat different methods of determining the negative pressure. Each of these methods was applicable to a specific moisture interval. With a high moisture content close to the field moisture capacity, and with a negative pressure interval ranging from -0.05 atm $> H > -0.5$ atm, the most accurate data could be obtained by using a tensiometer. This method was used under field conditions and subsequently checked in the laboratory. For this purpose, the soil in plots where tensiometers had been installed earlier at various depths was moistened up to the field moisture capacity, after which parallel determinations of the soil moisture and the negative pressure of the moisture were made as the moisture was used by the plants. Finely porous ceramic bacteriological filters were used as tensiometer cells. The cells were placed into the appropriate soil horizon through drill holes, equipped with casings. Particular attention was given to obtaining a good contact between the tensiometer and the soil, since this is a fundamental condition for successful work with tensiometers. To this end, in the first place, a sufficiently large contact area (20 cm^2) was used and, in the second place, the tensiometers were not removed from the soil until the very end of the experiment. The vacuum produced in the tensiometer, as the soil removed water from it, was measured by means of a mercury manometer having an accuracy up to 3 mm.

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[1] This work was done under the direction of Prof. S. V. Zonn in the forest soil science laboratory of he Institute of Forestry.

The labor in carrying out the field experiment required laboratory methods of determining the desired relationship. The investigations were made on soil samples with a natural structure, placed in aluminum boxes which were densely packed with the tensiometer. A pump was used to produce the required vacuum caused by removal of moisture from the soil, and this moisture was measured when the capillary equilibrium had been achieved. The soil samples were five cm in diameter and four cm in height. The results of the field and laboratory determinations turned out to be so close that it was thenceforth possible to limit the investigations to laboratory determinations. With a lower moisture content and a correspondingly low negative pressure ($-5.5 > H > -20$ atm), the negative pressure was determined by the temperature decrease of freezing of the mass of the soil and moisture, since these quantities are directly proportional to each other.

Determinations were also made on soil samples with a natural structure whose moisture was controlled by direct drying from the surface of the soil. This evaporation was done as slowly and uniformly as possible so as to avoid large moisture gradients which could decrease the accuracy of the determinations. The freezing was done in glass vessels sunk into a mixture of salt and snow, the temperature of which was several degrees below the required temperature for freezing. The freezing temperature was determined by the convexity of the cooling curve of the sample, constructed by the readings from the thermocouple (nichrome-constantan), which made it possible to measure the temperature to an accuracy up to 0.01° C and at the same time had a very low thermal inerta. When the soil moisture content was still lower (down to wilting moisture and below) and when the negative pressure became less than 20 atmospheres, it was most convenient to use a hygroscopic method keeping the soil and the water vapor above a salt solution with a known osmotic pressure until equilibrium had been obtained.

The disadvantage of the cryoscopic and hygroscopic methods is that they depend on the magnitude of the "total pressure of the soil moisture," which is equal to the sum of the negative (capillary) and the osmotic pressures. It may be assumed that in non-salt soils the osmotic pressure is somewhat smaller than the capillary and that its magnitude may be disregarded.

The data obtained by all these methods give a continuous ratio for each soil horizon. On a semi-logarithmic graph these are reflected by a family of curves (Figure 1) located almost parallel to each other. The complexity of these curves is due to the unequal distribution of pore diameters. The results obtained are fully reliable because of the large number of determinations (approximately 40 for each horizon).

The relationship between the coefficient of moisture conductivity of the soil and the content of moisture in the soil was studied by analyzing non-stationary moisture flow. The value of the coefficient in this process is calculated according to equation 3. With a high moisture content close to the field moisture capacity, the flux rate was calculated on the basis of data on the dynamics of the moisture in various soil horizons, obtained under field conditions in an area of clean fallow. At lower levels of moisture, it was more convenient to make the investigations on samples with natural structures. The downward flux of moisture and the upward movement to the evaporating surface are due to the gradient effect of the moving forces, the force of gravity and the negative pressure. Depending on the concrete conditions of the experiment, these gradients may be in the same direction or may be in different directions

$$(I = 981 \pm \frac{dH}{dl} \cdot \cos \varphi, \left[\frac{\text{barye}}{\text{cm}}\right],$$

where φ is the angle between the direction of the gradient of the negative pressure and the direction of the gradient of the force of gravity).

Although these processes are continuous in nature and their parameters are constantly changing, in order to facilitate calculations these continuous processes are broken up into a number of stages, each of which is considered as a single stationary process. The calculations were made by the method of graphic representation in the following sequence:

a) the changes in the volumetric moisture in time are laid out for the various soil horizons (1');

b) the rate of moisture change in the horizons is determined by differentiating these curves with time (2');

c) the successive addition of these rates in the direction of the flux characterizes the rate

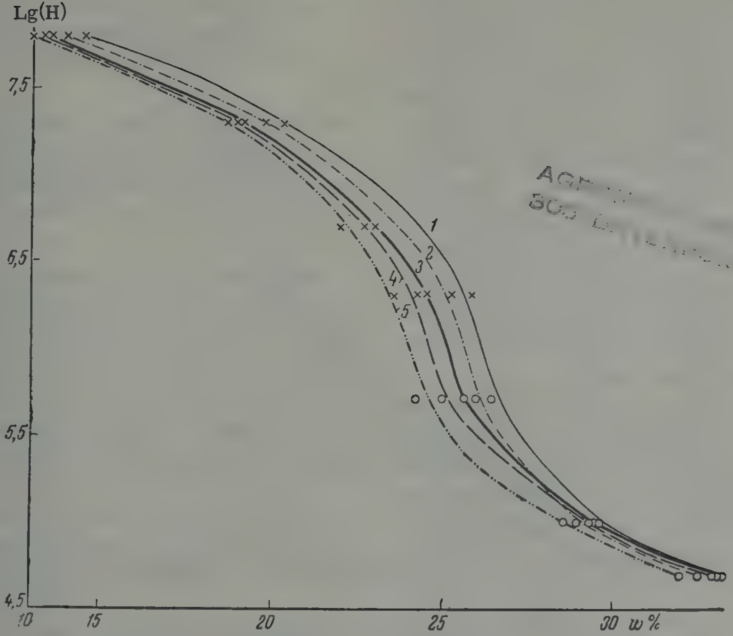

Fig. 1. Relationship between the negative pressure of the soil moisture (H, bar) and the soil moisture (w, % of volume).

Depth: 1-20 cm, 2-40 cm, 3-60 cm, 4-90 cm, 5-120 cm.

of the flux at the boundaries of the horizons (3');

d) on the basis of the relationship between moisture in the soil and the negative pressure of the moisture, curves are constructed of the change in the negative pressure with time (4');

e) the magnitude of the gradient is determined by differentiating these curves according to the length of the flux (5');

f) the coefficient of moisture conductivity is calculated on the basis of these two relationships (3') and (5') -- (6');

g) comparison of relationships (1') and (5') makes it possible to determine the relationship between the moisture in the soil and the coefficient of moisture conductivity (7').

In semi-logarithmic form (Figure 2), this relationship appears as an s-shaped curve. For the sake of the calculations, it was assumed temporarily that all the moisture within this moisture interval moves in liquid form. This assumption evidently led to no significant error, since the "specific rate" of the vapor in the general flux of moisture usually plays a noticeable role only when the soil moisture content is very low.

The results obtained indicate that the magnitude of the coefficient of moisture conductivity drops rapidly as the soil moisture decreases, down to very low values; after this it continues to decrease, but more slowly. The absence of any sharp bends in the curves for the negative pressure and for the coefficient of moisture conductivity indicate the conditional nature of the soil-hydraulic constants that have been used. The functional moisture properties at soil moisture contents corresponding to certain of these constants are shown in Table 1. It has thus far been impossible to determine experimentally whether the water moves primarily in capillary form or in film form. There is, however, certain indirect evidence that might throw light on this question. According to Poiseuille's Law for the laminar flow of liquid in capillaries, the rate of flow is directly proportional to the square of the radius of the capillary

$$v = k_1 \cdot R^2. \qquad (4)$$

Jura's approximate formula makes it possible to determine the average diameter of the pores filled with moisture, according to the magnitude of the negative pressure of the moisture.

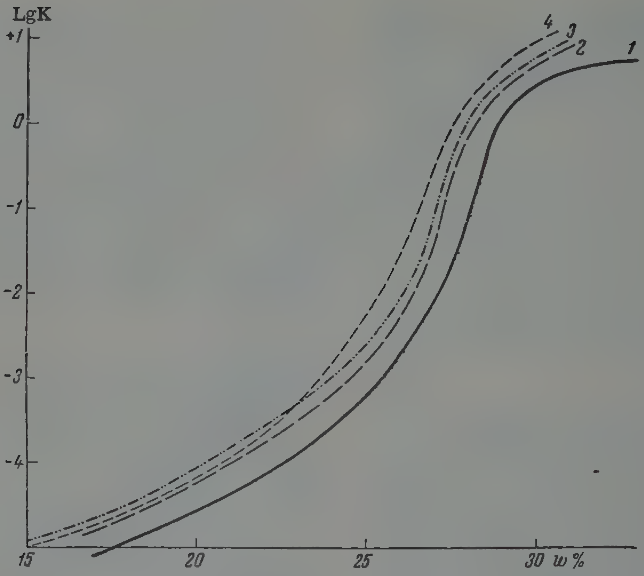

Fig. 2. Relationship between the coefficient of moisture-conductivity of the soil ($K \cdot cm^3 \cdot sec/g$) and the moisture (w,% of volume).

Depth: 1-30 cm, 2-45 cm, 3-70 cm, 4-100 cm.

Table 1

The magnitude of the negative pressure of the soil moisture under certain soil-hydraulic constants in a medium clay loam chernozem

Horizon, and depth, cm	Bulk density	Field moisture capacity		Moisture at capillaries		Moisture at permanent wilting	
		W	- H	W	- H	W	- H
A 20	1,15	28,7	$-1,45 \cdot 10^5$	20,1	$-2,09 \cdot 10^7$	18,2	$-3,39 \cdot 10^7$
A 40	1,20	27,6	$-1,58 \cdot 10^5$	19,3	$-2,40 \cdot 10^7$	17,7	$-3,39 \cdot 10^7$
B 60	1,30	28,0	$-1,51 \cdot 10^5$	19,8	$-1,58 \cdot 10^7$	17,2	$-3,16 \cdot 10^7$
BC 90	1,38	27,6	$-1,58 \cdot 10^5$	19,3	$-1,58 \cdot 10^7$	16,6	$-3,31 \cdot 10^7$
C 120	1,43	28,0	$-1,26 \cdot 10^5$	19,6	$-1,45 \cdot 10^7$	16,9	$-2,95 \cdot 10^7$

Note: 1. The moisture in the soil is expressed as percentages of the volume (W); 2. The negative pressure of the moisture is expressed in bars (-H); 1 atmosphere = 10^6 baryes.

Note: Comma represents decimal point.

$$R = \frac{k_2}{-H}. \qquad (5)$$

When there is a unit gradient of the negative pressure, the rate of the flux is also, accordingly, the coefficient of moisture conductivity:

$$v = K. \qquad (6)$$

In this case, for the flux of water in the capillary system one may write:

$$K = \frac{(k_1 \cdot k_2^2)}{H^2} = \frac{k_3}{H^2} = k_3. H^{-2}. \qquad (7)$$

In the medium clay loam soil studied in this experiment, the relationship between

K and H is so close to the above that it serves as indirect evidence of the validity of the assumption that in this moisture interval, the moisture movement is primarily in capillary form.

The most complex phase in these investigations turned out to be the study of negative pressure developed around the absorbing roots as the moisture was depleted. Data on the magnitude of the gradient may be obtained by two methods.

The first consists of determining the magnitude of the suction force in the peripheral cells of the root and the average values of the negative pressure of the soil moisture at this moisture content. Knowing the functional properties of the soil moisture, one may approximately calculate the negative pressure. In making these calculations, it must be remembered that there are great changes during a 24-hour period in the suction force of plants.

According to the second method, the moisture near the absorptive surface of the root is determined empirically, and then recalculated in terms of the negative pressure.

Only a few specific data on the suction force of oak roots (4) were available; it was considered possible to use data on the suction force of oak leaves during daylight hours (10), since it is known that the drop in the suction force within the plants is usually not great (6). In comparing the magnitudes of the suction force of oaks and the negative pressure of the soil moisture, it turned out that the former was always three to seven atmospheres higher than the latter. This is in full accord with the theoretical idea that there is a gradient of negative pressure in the vicinity of the absorbing roots. The reliability of these data was insufficient for making calculations, however, so that the empirical determinations of the moisture were used. The investigations were made under field conditions in young oak plantations.[2] Small samples (3-4 g) were taken from the freshly cleaned glass of the section at various distances from the small absorptive roots, and the gradient of the negative pressure at a distance of 0.5 cm from the roots was calculated from the moisture determinations. The results were treated by the statistical methods. The average arithmetic values of the gradient separately for each moisture interval (M), the standard deviation (σ) and the square-root deviations of arithmetic mean (m) were calculated. Data whose deviation from the arithmetic mean were more than 1.5 σ were rejected.

The criterion for the rejection was the reliability of the experimental results as evaluated by the Student-Fisher table. This showed that the probability of the average lying within the limits of $M \pm 1.5\ \sigma$ in six replicates amounted to only five percent. The number of data rejected was no more than 10-15 percent. This principle was often used in determining the functional properties of the soil moisture where, in addition, extensive use was made of the principle of the "sliding mean" (1). The need for comparatively complex methods of treating the data is dictated by the fact that the original materials of soil moisture produce a great deal of statistical dispersion, because of the non-homogeneity of the soils, whereas differentiation requires a high degree of accuracy in establishing the desired relationships.

The relationship between the magnitude of the gradient at a distance of 0.5 cm from the roots and the average moisture in the soil at a depth of from 20-40 cm from the surface is shown in Figure 3. It appears that the gradient is very small with a high moisture content close to the field moisture capacity, but as the moisture content decreases, this rapidly increases to 10 baryes/cm. As the soil moisture decreases further the gradient, for a while, remains at the same level, and then again drops sharply almost to zero, as the moisture content approaches the wilting moisture content. This abrupt drop in the gradient is apparently due to the fact that the suction force of the peripheral cells of the root reaches a certain physiological limit during this time, whereas the negative pressure of the soil moisture continues its steady decrease.

The relationship between the rate of flow of moisture toward the absorptive surface of the root and the level of soil moisture was calculated according to equation (3), on the basis of the parameters obtained. For convenience in examining the curve which expresses this relationship on the graph (Figure 3), the curve should be divided into three intervals along the axis of the soil moisture.

In the first interval (from the field moisture capacity to the middle of the range of available moisture, or from 100-50% of the maximum amount of available moisture), the coefficient of moisture conductivity of the soil rapidly decreases; because of the increase in the gradient of negative pressure, however, the rate of the moisture flow remains unchanged. The small magnitude of the gradient indicates that the moisture supply to the absorptive root surfaces is not hindered, and that the "vena contracta" which limits the transpiration is the resistance to the water flow within the conductive system of the plant itself. This is also affected by atmospheric factors.

In the second interval (from 50-15% of the

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[2] The field moisture investigations were made with A. F. Lisenkov.

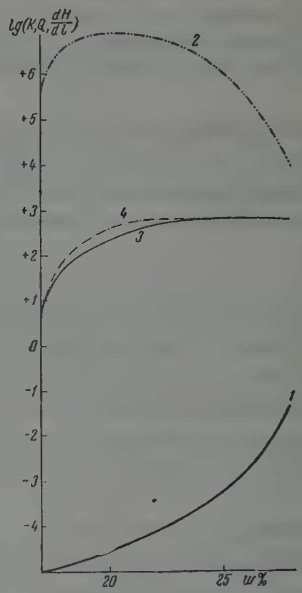

Fig. 3. Relationship between the moisture use by Oaks ($Q \cdot cm^3/sec$), the soil's moisture-conductivity coefficient ($K \cdot cm^3 \cdot sec/g$) and the negative pressure gradient of the soil moisture (-H bar), and the soil moisture (w, % of volume).

1 - coefficient of moisture conductivity of the soil;
2 - negative pressure gradient of the soil moisture;
3 - rate of moisture use (as calculated); 4 - rate of moisture use (as determined).

maximum supply of available moisture), the moisture conductivity of the soil continues to drop sharply; but because of the fact that the negative pressure of the moisture is still great, the plants continue to maintain the rate of moisture flux at a high level, by increasing the suction force of the peripheral cells of the root and thereby developing a high gradient of negative pressure in the soil surrounding the root.

In the third interval, immediately above the wilting moisture, the moisture conductivity decreases more slowly, although the further decrease in the negative pressure sets a limit to the growth of the gradient and the flux rate drops sharply to very small magnitudes.

In order to check the accuracy of these investigations, the relationship between the rate of soil moisture use and the amount of soil moisture was determined empirically under field conditions on the same objects of investigation, by means of graphic differentiation of the curves reflecting the changes in the soil moisture with time. Comparison of the empirically obtained and the calculated relationships between these two quantities show a high degree of correspondence (Figure 3).

The presented facts show clearly that the processes associated with the moisture movement may be investigated satisfactorily only by studying the static and dynamic properties of the soil moisture.

Further investigations in this direction should be made in order to solve the following problems:

1. Calculation of the cylindrical stream of moisture toward the roots under a given negative pressure.

2. Calculation of the rate of moisture use from the soil by plants with a given absorptive surface in the roots, a given geometry of the root system, and a given field of negative pressure.

3. Calculation of the negative pressure under a given physiological reaction of the plants to changes in the soil moisture properties, the magnitude of the absorptive surface of the roots, and the geometry of the root system.

CONCLUSIONS

1. The availability of soil moisture to woody plants is directly related to the suction force of the roots, the negative pressure of the soil moisture, and the conductivity of the soil moisture. The relationship between these magnitudes is expressed by the formula

$$v = -K\cdot\frac{dH}{dl}\ \left[\frac{cm}{sec}\right],$$

where $v\left[\frac{cm}{sec}\right]$ is the rate of moisture flow towards the absorptive surface of the roots, $\frac{dH}{dl}\left[\frac{barye}{cm}\right]$ is the gradient of the negative ressure close to this surface, and

$k\left[\frac{cm^3 \cdot sec}{g}\right]$ is the coefficient of moisture

onductivity of the soil.

2. With a gradual decrease in the soil moisure content, the negative pressure of the moisture and the coefficient of moisture conductivity decrease rapidly. The relationship between these magnitudes is expressed, to he first approximation, by the inverse quadratic ratio ($K = k \cdot H^{-2}$).

3. With a decrease in the moisture, the suction force of oak roots gradually increases, at first slowly and then more rapidly; this results in the development of a considerable negative pressure gradient close to the absorptive surface.

This increase in the gradient makes it possible to maintain a high rate of moisture flow, in spite of a decrease in the moisture conductivity of the soil. When a certain physiological limit is reached, however, (for drought-resistant forms of oak this is in the interval between 30 and 40 atmospheres) the suction force ceases to grow, the gradient of the negative pressure drops rapidly and the moisture flow toward the roots gradually fades away.

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METHODS USED IN THE TREATMENT, GRAPHIC REPRESENTATION AND ANALYSIS OF DATA ON THE SOIL MOISTURE DYNAMICS

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The development of ideas on the moisture regime in soils has always been accompanied by the elaboration of new methods of representation and consequently of analysis of data on the soil moisture. These methods are not merely narrow technical problems, but involve questions of principle which usually lie at the basis of new theoretical concepts.

This article presents the results of the elaboration of two chief methods of representation and analysis of data on soil moisture dynamics: the curve method and, in particular, the isopleth method. The figures shown below (1-4) which illustrate the methods suggested by one author, have been drawn on the basis of the same object of study -- a dark-colored soil found on a loess-like clay loam under virgin herbaceous-grass vegetation (in the Dzhanybek Experimental Station, Academy of Sciences, USSR in the Western Kazakhstan oblast'; data from 1951). Descriptions of these soils may be found in papers by soil scientists at the experimental station (2, 12).

The curves usually express the distribution of moisture (as percentages of the dry weight of the soil) in the soil profile at a specific time, and a series of curves presents the changes in the soil moisture content (Figure 1b); as suggested by Vysotskiy (4) this presentation may also be shown in the form of isopleths (Figure 2a).

The amount of gravimetric moisture, however, is a poor reflection of the degree of saturation of the soil profile,[1] which has different moisture-retaining capacities in different horizons. Thus, for example, when the gravimetric moisture content is 18% in the humus horizon of a clay loam chernozem where the FMC[2] is equal to 35-40%, the soil is almost dry WM = 14-15%), whereas in the carbonate horizon the soil is almost fully saturated (FMC = 18-20%). It has therefore been suggested that the soil moisture should be indicated by relative quantities as percentages of the full moisture capacity, the capillary moisture capacity and the field moisture capacity. The latter method, which corresponds to the most frequently encountered case of limiting saturation of moisture (with deep ground waters) has come to be the most widely used.[3] A corresponding "isopleth method" (Figure 2b) has also been developed.

This method too, however, soon ceased to satisfy investigators; it gave only a formal representation of the soil moisture content without indicating the nature of the moisture. Graphs of the type shown in Figure 2b did not show soil layers which had been dried to the WM or the MH, and the changing ratio between the WM and the FMC in the soil profile created difficulties in analyzing the moisture regime in the soil. Thus a number of tables by Dolgov (5) and by Rode and his colleagues (3, 16) have used one more variation of the "isopleth method" which consists in distinguishing soil layers according to these or other qualitative "moisture categories" corresponding to specific soil-hydraulic "constants" or to the moisture intervals between them. A. A. Rode has distinguished a layer with MH and a layer with less than MH, a layer from MH to WM, a layer with WM, a layer from WM to FMC,

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[1] N.A. Kachinskiy, "Soil Moisture and Methods of Studying it." Izd. NKZ "Novaya Derevnya," Moscow, 1924.

[2] Abbreviations used (after A.A. Rode): MH - maximum hygroscopic moisture, WM - wilting moisture, FMC - field moisture capacity, DCM - discontinuous capillary moisture, RAM - range of available moisture (FMC - WM), SMC - saturation capacity, PD - particle density, BD - bulk density.

[3] For special purposes, or under certain specific conditions, the moisture is now also calculated as a percentage of the capillary or the saturation moisture capacity.

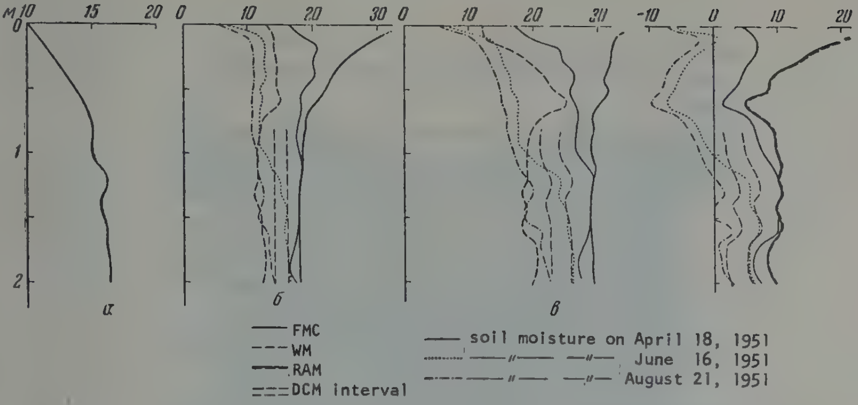

Fig. 1. Moisture characteristics in the soil profile, according to the curve method:

a - bulk density, g/cm^3; b - "gravimetric" moisture as a percentage of the weight of dry soil; c - "volumetric" moisture as a percentage of the soil's volume; d - available moisture as a percentage of the volume.

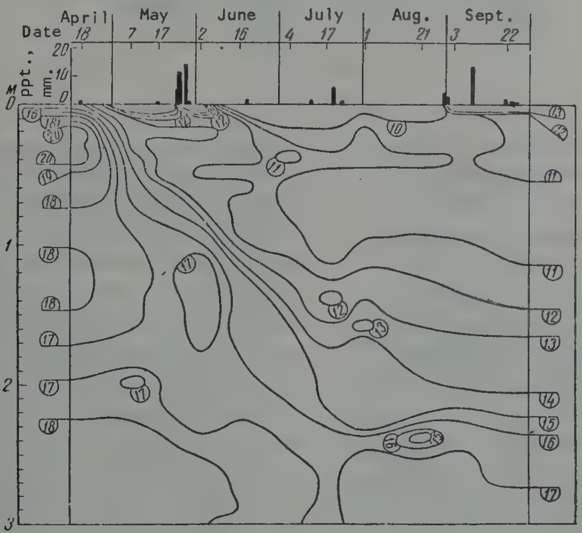

Fig. 2a

a layer with FMC, and a layer from FMC to SMC. The moisture intervals between WM and FMC and between FMC and SMC have been divided arithmetically, the first into four and the second into two parts. Later on, with the appearance of the concept of a DCM (1, 3, 17) this method would supplement it. In many cases it has been possible to distinguish a layer with a DCM or even to divide the interval between WM and FMC (that is, the RAM) into equal halves, because for a number of carbonate soils the average RAM and the DCM interval are very close to each other. Moisture, isopleths as weight percentage have begun to be superimposed on the layer with various moisture "categories" (Figure 2c; the average of the range of available moisture here corresponds to the average value of the DCM interval -- in the carbonate horizons this is less than 0. 5 m). Three basic variations of the isopleth method

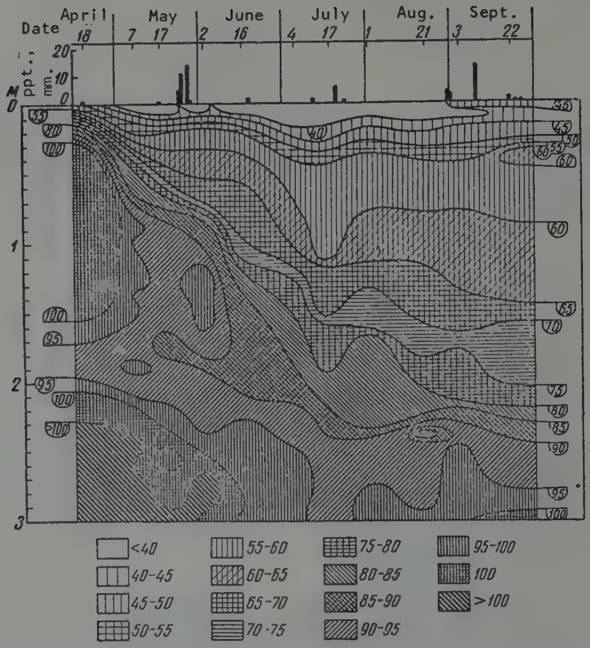

Fig. 2b

(Figure 2a, b, c) are known in the soil-hydraulic literature. These are based on the soil moisture as a percentage of the weight.

As a result of the development of soil hydrology and the physics of capillary porous bodies, in the past ten years there has come to be a tendency to explain many soil-hydraulic phenomena by the action of capillary forces (in papers by S. I. Dolgov [4, 5] and others; by Deryagina, Nerpina and Mel'nikova [7] and others; and by A. A. Rode [17] and others).

It must be acknowledged at the present time, however, that moisture expressed as a percentage of the weight may not be the only characteristic of the soil moisture. Water is withheld and moves about through pores in the soil in quantities measureable above all by units of volume, and its physical condition depends primarily on the physical condition of the soil (compaction, structure, aggregates, and texture). Therefore in studying the moisture regime in the soil, the moisture content must be characterized not only as a percentage of the weight but also as a volume percentage of the soil -- i. e., by the relationship of the volume of water to the volume of soil which contains it. Another advantage of using volume percentages is the fact that, since these are determined for each 10-cm layer of the soil, they will be numerically equal to the amount of water in the same layer as expressed in millimeters. The use of volume percentages also eliminates the lack of correspondence between the actual amounts of water contained in soil layers which have the same thickness but different BD (these amounts are not comparable if they are expressed in terms of percentages of the weight). In addition, the use of percentages of the volume eliminates the lack of correspondence in the amounts of moisture when expressed as percentages of the weight that is due to differences in the specific weight of different soils and their genetic horizons. When the moisture is expressed as percentages of the volume, changes must be made in both the above-indicated methods of representing the data (Figure 3a). In order to analyze the dynamics of soil moisture, the representation of the moisture in the form of isopleths must be accompanied by a superimposition of "qualitative categories" of moisture.

In Figures 1b and 1c one may compare the moisture profiles expressed as percentages of the weight and as percentages of the volume (data are given only for certain typical periods of time). The main cause of the discrepancy between them is the effect of the bulk density (BD) and its change throughout

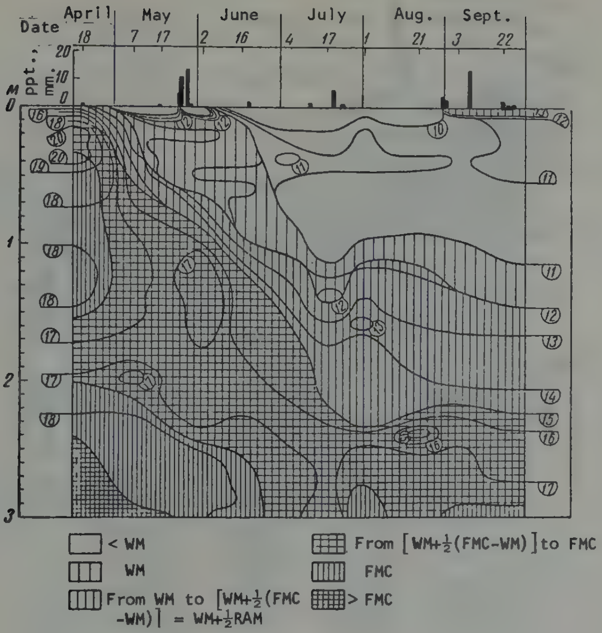

Fig. 2c

Fig. 2. Representation of the changes in the "gravimetric" moisture by the chronoisopleth method:

a - chronoisopleths of the "gravimetric" moisture (after G.N. Vysotskiy); b - chronoisopleths of the "relative gravimetric moisture" as percentages of the FMC; c - chronoisopleths of the "gravimetric" moisture with "qualitative categories" of moisture.

the soil profile.[4] As early as 1923, S. N. Tyuremnov (18) determined that as a clay loam soil becomes denser, moving downward in the profile (with no change in the texture), the magnitude of the FMC as a percentage of the volume remains almost constant, whereas the magnitude of the WM (which is moisture not available for plants) increases; as a result, there is a decrease in the amount of available moisture when the FMC corresponds to the range of available moisture (RAM).

These facts have been explained only in recent years on the basis of a study of the microstructure of clay loam soils (13, 14). By comparing the porosity as calculated under the microscope in thin sections with the volumetric magnitudes of the FMC and WM, it has been possible to show that the available moisture of the FMC is located primarily between the microaggregates and the particles of the loess-like structural-particle fraction (the structural-particle fraction is that fraction in which the aggregates and the ultimate particles are equal in size). The moisture corresponding to the WM is associated mainly with the pores within the microaggregates of this fraction. Thus, physically speaking, the RAM corresponds to a "body of water" which is limited by the surface of the loess-like particles and microaggregates (more precisely by the surface of the moisture film associated with these microaggregates), and by the complex surface of the system of menisci and the films connecting them -- the surface separating this body of water from the air in the large pores of the soil. It is this "body of water" which should be kept in mind in studying the regime of liquid moisture,[5] since the amount of water

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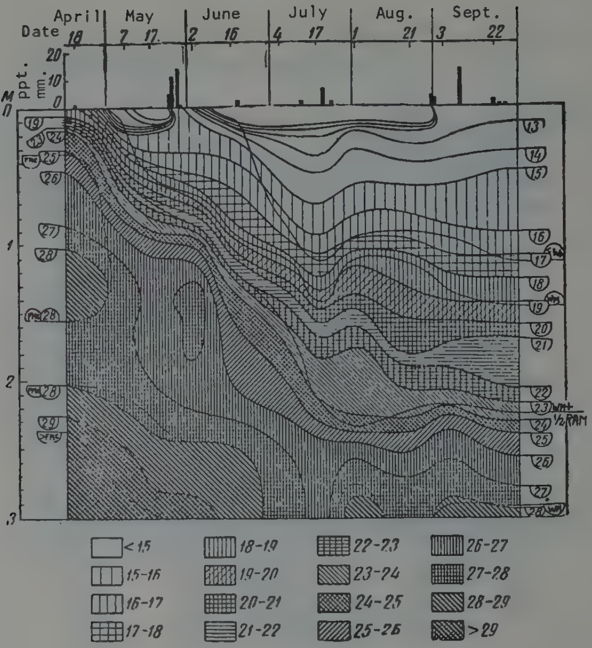
[4] The soil textures at the Dzhanybek Station scarcely changes throughout the profile; these are loess-like clay loams, coarse silts (according to A.N. Kachinskiy's classification).

[5] N.A. Kachinskiy calls only this part of the moisture "capillary" (8, 9).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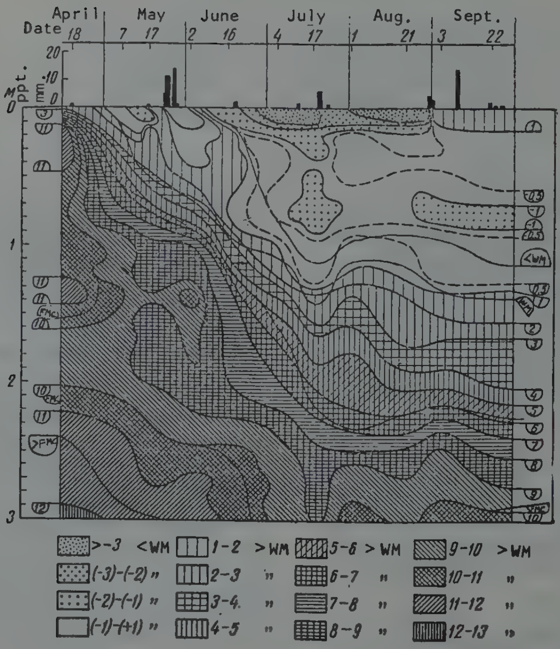
2.5-2.6
2.6-2.7
2.7-2.8
2.8-2.9
>2.9

Fig. 3a


April
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ppt. mm.
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3-4 "
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9-10 >WM
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Fig. 3b

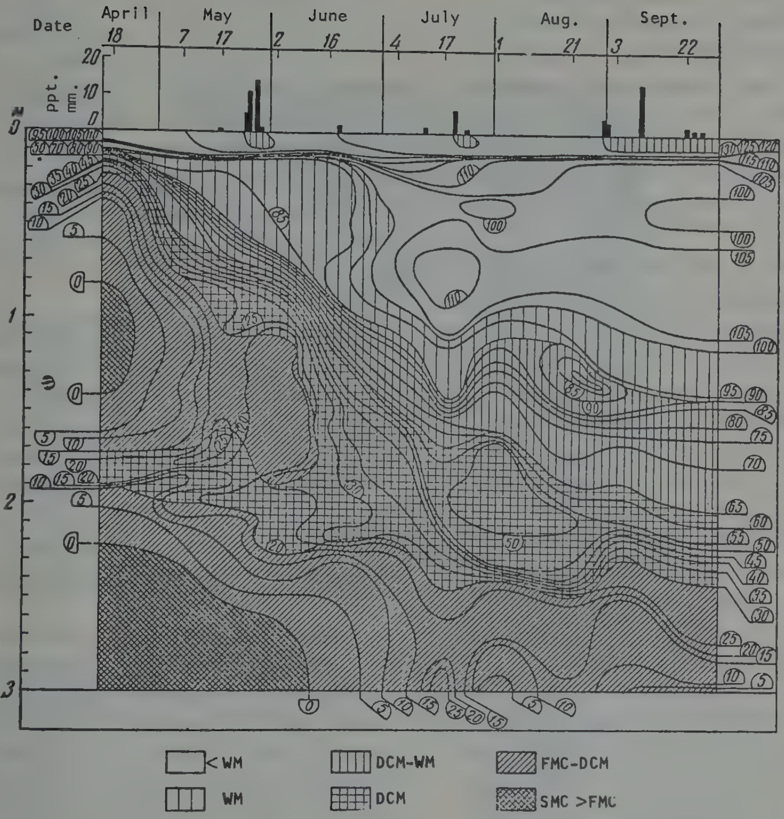

Fig. 3c

Fig. 3. Representation of the changes in the "volumetric" moisture by the chronoisopleth method:

a - changes in the moisture as a percentage of the soil's volume (with or without the qualitative categories); b - changes in the available moisture (with or without the qualitative categories); c - changes in the relative degree of non-saturation of the soil by available moisture, with the qualitative categories of moisture.

corresponding to the WM associated with the solid phase (in the form of adsorbed films and sorbed isolated microaccumulations within the loess-like microaggregates) has almost no capillary movement and for all practical pruposes does not move in liquid form.

Curves (Figure 1d) and isopleths (Figure 3d) in conjunction with superimposed "qualitative categories" of moisture[6] are also used to study the distribution throughout the profile and the dynamics of the free moisture available for plants.

Analysis of the data as represented in a diagram of the type illustrated in Figure 3b will, above all, show the changes in the content of moisture remaining in the soil after part of this moisture has been consumed by plants. But the available moisture is free moisture (not bonded) and thus has some degree of mobility; in studying it, one is studying the movement of liquid water, which is one of the most important tasks in understanding the water regime of a soil. There is still no knowledge of the difference between the forces which produce various rates of moisture movement. The magnitudes of these forces and the amounts of moisture movement depend both on the moisture contents at which movement takes place and on the porosity of the layers and horizons within which the water moves, and on the combination and alternation of such horizons. Thus this problem is a very complex one. The problem still remains to find some method of analyzing soil moisture which would enable one to judge, first, whether any movement of liquid moisture is possible and, second, the direction of this movement.

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[6] In the agricultural meteorological service it has also become customary to represent the productive moisture in mm by chronoisopleths (15).

What are the factors that affect the possibility of movement? Movement of liquid moisture will be impossible if the moisture in the soil is in a condition of "equilibrium." The SMC may be taken as the equilibrium of the moisture in the soil profile, at its greatest level of humidity (within the effect of the capillary fringe). A number of papers in recent years have shown that, at the FMC, the moisture gradually moves downward (even when the temperature[7] is constant) as a result of the gravity force. This downward movement, however, is so slow that the magnitude of the FMC_{15},[8] in the loess-like clay loam under investigation here can be considered as being practically in equilibrium. Thus at the FMC there should be no gradient of capillary forces producing a moisture movement within the body of water corresponding to the RAM.

Movement may take place if the "equilibrium" between layers of the soil is destroyed, for example, by moisture used from one layer while the original moisture content is retained in another. Under these conditions a difference in forces (primarily capillary) will arise between these layers and there will be a movement of moisture toward the layers in which there is "a deficit of equilibrium" or, in other words, a deficit of available moisture. Such movement must continue until the establishment of a new equilibrium with a moisture content which is lower than the FMC (when there is a certain minimal vertical gradient without which there can be no movement).

It is possible that the conditions for the water movement should be judged on the basis of the deficit of available moisture or, more accurately, the difference in the deficit gradient,[9] and also of the changes in the moisture from season to season. In this case the dynamics of the deficit of available moisture would again be represented in the form of isopleths and would reveal a picture similar to that of Fig. 4a, with the difference that the moisture use would be calculated for each period of time not on the basis of the specific initial moisture content in spring, but on the basis of the FMC. It appears, however, that this method should not be used, primarily because of the nature of the RAM.

It is well known that the RAM includes no less than two intervals of available moisture which differ sharply in regard to movement: the interval from the FMC to the DCM and the interval from the DCM to the WM.[10] In the first moisture interval the capillary movement is very distinct and in the second interval very indistinct (1, 17). Therefore with the same absolute gradient of the deficit of available moisture, the possibility of moisture movement will be completely different in the layers of soil containing moisture of different intervals of availability (WM to DCM and DCM to FMC).

Consequently the difference in the available moisture deficits which determines one gradient or another cannot of itself be used to judge the possibility of movement. In addition, the magnitude of the RAM changes in relation to the physical condition of the soil; in the case of the Dzhanybek loess-like clay loams, it changes within the carbonate horizons (below 0.5 m) and within the parent materials which have the same microstructure. This depends mainly on the magnitude of the BD (11, 14, 18). The same absolute deficit of available moisture in layers with different BD will indicate different degrees of non-saturation of the soil with available moisture. Apparently the same degree of saturation of two layers of soil is determined by the same relationship between the available moisture and the magnitude of the RAM, so that

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[7] Heating of the soil intensifies the downward moisture movement (see, for example, the chronoisopleths for the moisture in July), whereas cooling retards them and may even reverse the movement (upward). Slow capillary-gravitational movement also takes place at the FMC, in spite of the thermocapillary movements that frequently mask it.

[8] Suggestion is made of adding to the symbol FMC a subscript to indicate the number of days that have passed the irrigation of the plot and the determination of the moisture in the soil profile. FMC_{15} thus indicates the field moisture capacity of the soil profile 15 days after the irrigation.

[9] By the gradient of the deficit of available moisture is meant the "change in the deficit of available moisture to the FMC, per unit of length." In this sense one may speak of a "deficit gradient" of any other equilibrium condition with moisture contents lower than the FMC.

[10] Recently the DCM has been defined in a number of cases not as a threshold, but as a special moisture interval with a definite connection to the microstructure. The DCM, in its usual sense, is in this case the upper limit of this interval. In accordance with the "DCM interval," a layer with a DCM is distinguished in the soil profile and a "DCM zone" on the dynamic isopleth graph (See Figure 3C).

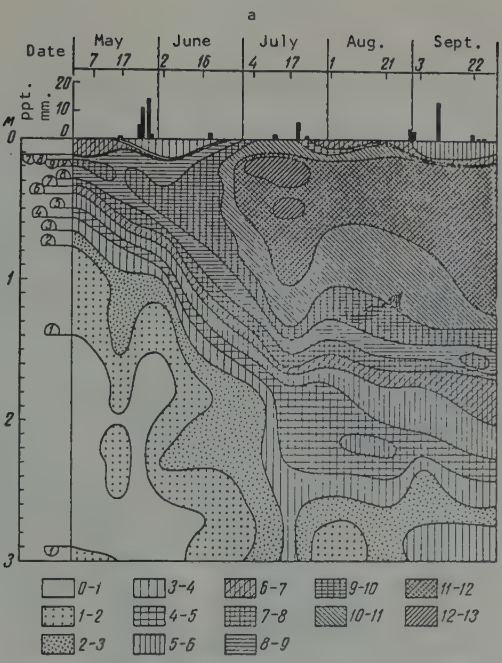

Fig. 4a

the same degree of non-saturation is determined by the same relationship in the deficit of the available moisture and the magnitude of the RAM. The main criterion for the non-equilibrium condition of the soil moisture may be the difference in the degree of non-saturation of the soil with available moisture expressed as a percentage of the RAM -- i. e.

$$\frac{\text{deficit of available moisture}}{\text{RAM}} \times 100\%.$$

The same thing may be expressed by the degree of saturation of the soil with available moisture, or the "relative available moisture." To find the soil's capacity of yielding moisture to plants, one may represent the relative available moisture by means of isopleths on which the magnitudes of the various moisture categories have been superimposed. In order to determine the dynamics of the non-equilibrium condition of free moisture and the possibility of its movement, it was suggested using a similar method of depicting the dynamics of the relative deficit of free available moisture in the form of isopleths, also with a superimposition of "qualitative categories" (Figure 3c). In this case it is convenient to use a combination of isopleths and curves.

All that has been said previously relates to the estimation of the amounts of moisture contained in the soil. Frequently, however, it is necessary to deal not with the amount of this residual moisture, but with the moisture which is used from the soil, comparing this amount with the factors of consumption (above all with the activity of plants, for the estimation of which the graphs of the moisture dynamics should be accompanied by graphs showing the root distribution and root development, as well as data on the top growth, the moisture contained in them, the amount of transpiration, etc.). Figure 4a shows isopleths depicting the increase in the amounts of moisture used up from the soil (under the same herbaceous virgin vegetation). This method of depiction is useful mainly in finding the abilities of the various layers of the soil to provide moisture. If the soil in springtime was saturated to great depth and the original moisture was equal to the FMC, such a graph will show not only the dynamics in the increase of the expended moisture, but also the increase in the absolute moisture deficit (both general and available), which must also be known in studying the problem of securing water for plants, the changes in the air content, etc.

Figure 4b shows a special method of treating data, in a comparative study of the transpiration intensity and the use intensity of soil moisture, as well as in studying the problem of the ability of various horizons of the soil to provide moisture. This is the "intensity use per layer" or the "dynamics of the average daily moisture use by layers" from the soil.

This method makes it possible to determine

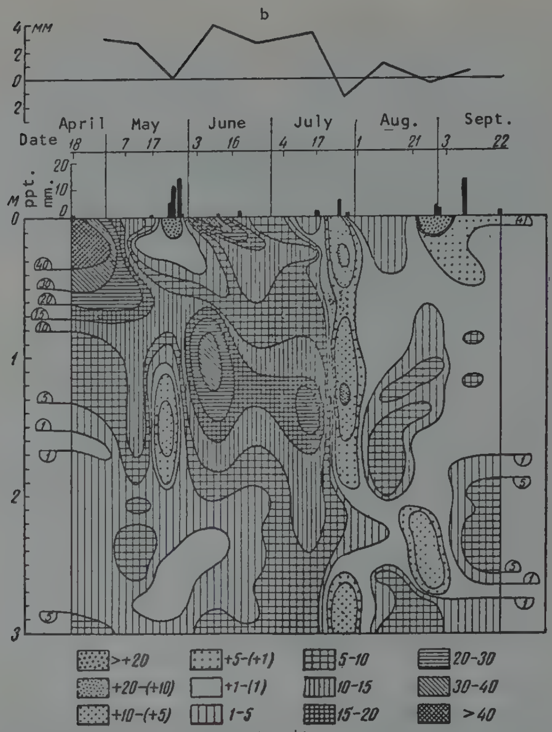

Fig. 4b

Fig. 4. Some special methods of treating data on the moisture as a percentage of the soil's volume:

a - changes in the increase in the amount of moisture used from the soil; b - changes in the average daily moisture use per layer of the soil (the use intensity). The curve at the top shows the changes in the total average daily moisture use from the soil.

on what dates of each vegetative period, from which parts of the profile and with what intensity the vegetation takes moisture, under given weather conditions and with a given original content of moisture.

In studying the regime of water vapor in the soil it is also convenient to use the method of chrono-isopleths as applied to the representation of the changes in the content of air in the soil profile. This is a very important factor in estimating the diffusion of water vapors and the exchange of gases with the atmosphere.

Mention must still be made of the method of topoisopleths, which characterize the moisture in the soil in space at any given moment of time (this was first suggested by G.N. Vysotskiy). A series of such topoisopleths constructed for different times will produce a picture of the changes in the moisture. Figure 5 shows an isopleth depicting the moisture use in 1956 by the soils of a solonetz complex[11] throughout a profile which intersects the main components of the complex. This method, supplementing the usual toposiopleths of the moisture in fall (the "gravimetric" moisture plus moisture "categories" -- as in Figure 2c), clearly shows the ability of different soil horizons to yield water to plants. Figure 5 also shows: 1) the symmetry in the yield of moisture to plants by different areas of dark-colored soil which are at equal distances from the center of the depression, because of the changes in the nature of the soil from the center toward the periphery of the depression and the concentric nature of the species composition of the vegetation, and 2) the capability of various layers of the soil of yielding different amounts of moisture to plants.

The following must be noted in conclusion: analysis of the changes in the soil moisture requires the use of various and, normally, several methods of treating and representing data, or of a combination of methods (which will vary depending on the purpose of the investigation), without which it will be impossible to analyze either the water regime in the soil or the consumption of moisture by the vegetation.

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[11] Of the Dzhanybek Station.

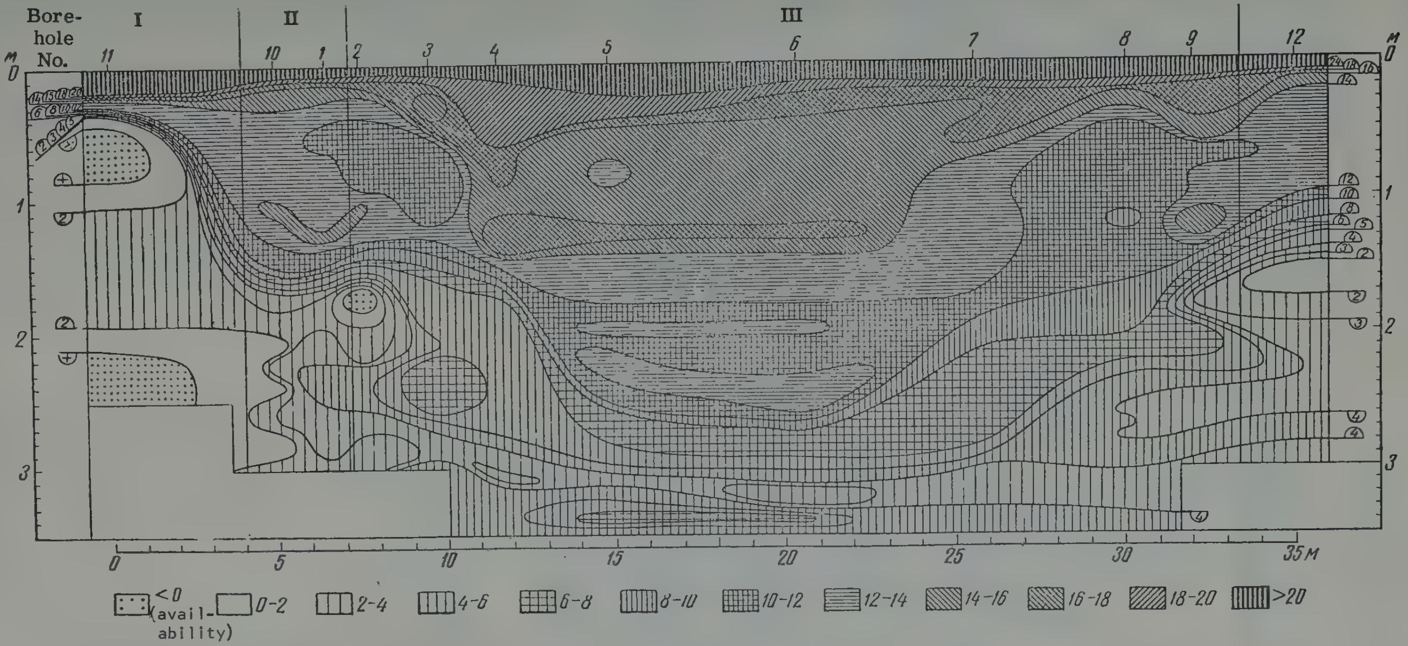

Fig. 5. Topoisopleths showing the moisture use from the soil during the spring-summer-autumn season of 1956 throughout Profile No. 1 (mm per 10-cm layer):

I - solonchak-like solonetz; II - light chestnut soil; III - dark-colored bottom soil.

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DETERMINATION OF AVAILABLE POTASSIUM CONTENT OF SOILS BY MEANS OF AN ILLUMINATING-GAS FLAME PHOTOMETER

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The chemical method of determining the mount of potassium in the soil is not suffi-iently accurate and is too laborious. The otassium content is, therefore, determined y means of flame photometers with interfer-nce light filters and operating on acetylene. his method has the advantage of a great de-ree of precision and can be used to make umerous analyses in a short time (1, 2).

The presence of calcium, which is excited n the acetylene flame, has a great effect upon he determination of potassium in the acetylene ame by means of ordinary low-selectivity ght filters (its line is close to that of potas-ium). In order to eliminate this problem, ertain investigators (3, 9) recommend remov-ng the calcium ion from the solution. When n acetylene flame is used, according to . Rusanov and his colleagues (4), the pres-nce of 0.2% of calcium in the solution has no ffect on the determination of hundredths of a ercent of potassium.

Some authors have suggested using flame hotometers in which the light filter is re-laced by a monochromator. The weak photo urrents that are produced by this apparatus re increased by means of photoelectric am-lifiers (5) or by light intensifiers (6). Semi-onductor photoresistors (7) have recently een used in flame photometry.

This article presents the results of deter-ining potassium content by means of a flame hotometer operating on illuminating gas. The ight filters in the photometer were prepared n the chemical laboratory of the Estonian Scientific Research Institute of Agriculture nd Melioration. Figure 1 shows an overall view of the apparatus and Figure 2 a diagram. The apparatus operates as follows: from the compressor (1) the air passes through an air reservoir (2) and a stop-cock (4) into the air-et of the atomizer. The air pressure is shown on a manometer (3). In order to obtain a constant air pressure in the intake vent of the compressor, an ordinary rubber tube (5 mm in diameter) with a stop-cock (8) has been introduced. To the head of the stop-cock has been attached a rod 25 cm long, on which there is a graduated scale. Thus the air pressure can easily be regulated by means of the stop-cock. When the current of air through the stop-cock (8) decreases, the pressure in the manometer (3) decreases and vice versa. By means of this installation, it has been possible to maintain the air pressure in the manometer and the air jet at the desired level for long periods of time without the use of a special regulator.

The solution to be investigated is vaporized by the atomizer and carried by the current of air through a bent glass pipe (5 mm in diameter) into a glass sphere, in which the droplets of the solution are mixed with illuminating gas. The pipe (which is 5 mm in diameter) emerging from the glass sphere is terminated by a quartz mouthpiece which forms the burner. According to the potassium content in the solution, the flame produces a typical emission spectrum, which is passed through a rubber condenser (5) and a light filter (6) to a FESS-U silver sulfide photoelectric cell, which has a diameter of 1.9 cm (7) and a sensitivity of 8,000 μA/l. The photocurrent produced in the photoelectric cell passes through a GZS-47 glass galvanometer, whose sensitivity is 2,000 mm/μA. An electric bypass with a resistance of 1,200 ohms is connected in parallel to the terminals of the galvanometer. Bituminous coal gas which enters Tallin from the gas works at Kokhtla-Yarva is used to operate the flame photometer. The gas enters the apparatus directly from the gas pipe through a stop-cock (9), by means of which the gas intake is maintained at a pressure of 15 to 20 mm, according to the water manometer. This pressure was determined experimentally.

A calibrated graph is prepared for previously known concentrations of potassium in the K_2O solution amounting to 2, 5, 10, 20, 30 and

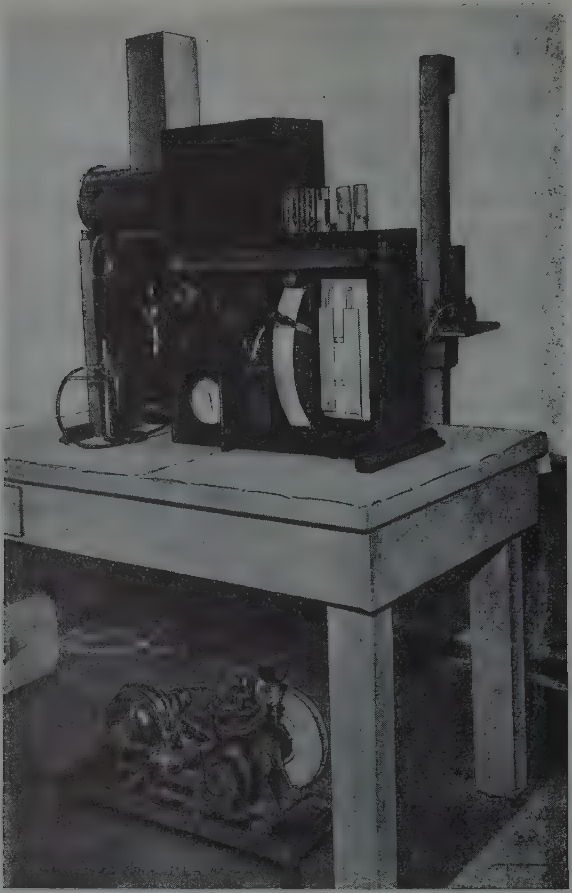

Fig. 1. Overall view of the flame photometer.

40 mg/l. The galvanometer readings are plotted on the vertical axis and the corresponding concentrations of K_2O on the horizontal axis. The described equipment produces a linear function: when the concentration of K_2O is 2 mg/l, the galvanometer reading is 5 mm; when the concentration is 20 mg of K_2O per liter, the galvanometer reading is 54 mm; and when the concentration of K_2O is 40 mg/l, the galvanometer reading is 110 mm. The flame condenser, filter and photoelectric cell are shielded from outside light by a tin cylinder, the inner surface of which is coated with carbon black. To the cylinder is attached a tin pipe for the removal of the products of combustion, which may be led off into the ventilation system. In the lower part of the cylinder there is an elongated opening for focusing the position of the flame in the condenser. The cylinder is attached to a wooden base. For convenience in operation, the manometer, the stop-cocks for regulating the flow of air and gas, the glass scale and the galvanometer illuminator are mounted on the front wall of this base.

The atomizer for this apparatus was prepared in the laboratory from the shell of a Liebig cooler, to which nozzles with openings 0.6 mm in diameter were soldered with Wood's metal. The end of the atomizer was fitted with a rubber plug through which was passed a bent glass pipe for removing the vaporized liquid. The lower edge of the rubber plug contained a hole for a small rubber pipe for the removal of the liquid accumulated in the atomizer.

The light filter was made from ordinary photographic plates 9 x 12 cm in size, from which the silver bromide was removed by a fixing bath; these were then dried after being carefully washed. Red and blue light filters were prepared from the photographic plates.

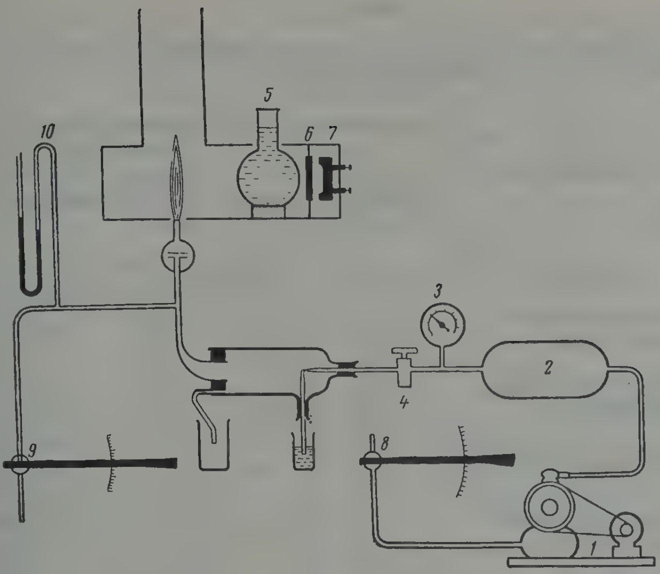

Fig. 2. Diagram showing the operation of the flame photometer.

In preparing the red light filter, 240 mg of "Bordeaux red" were dissolved in 10 ml of water. The resulting solution was spread evenly over the gelatin layer of the photographic plate. For the blue light filter, 60 ml of indigocarmine were dissolved in 10 ml of water and the solution was spread over the second light filter in the same manner. After drying, the light filters should be completely transparent. The best results were obtained by using a complex light filter consisting of two red and two blue filters. The required filter density was established experimentally. Figure 3 shows the spectrum characteristics of these light filters. These light filters have no greater selectivity than the ordinary light filters prepared by other authors (4).

The results of the determination of available potassium in soil extracts with the use of the light filter prepared in the manner described previously turned out to be very close to those obtained from selective interference light filters (some examples of these determinations are given in Table 1). This is due to the fact that the main admixture element -- calcium -- is considerably less excited in an illuminating-gas flame than in an acetylene flame.

Thus results were obtained with the previously-described photometer which agreed closely with the data on the determination of potassium by the Egner-Riehm method (9), (using a calcium lactate extract with a CaO content of 700 mg/l), both in the presence of calcium and after its removal from the solution.

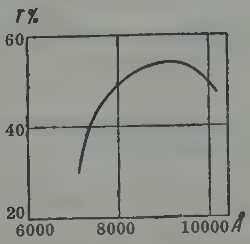

Fig. 3. Spectrum characteristics of the prepared light filters.

Table 2 compares the results of determination of the available potassium in various soil extracts by means of the previously-described photometer and by the chemical method using cobalt nitrite.

Determination of the potassium in the humus-illuvial horizons of soil under forest vegetation by the Kirsanov method (directly from the hydrochloric acid extract) produces much higher results. The hydrochloric acid extract from these soils has a dark brown

Table 1

A comparative determination of the available potassium in the soil (K_2O in mg/100 g of soil)

Soil and locality	Interference light filter		Laboratory-made light filter	
	Individual determinations	Average	Individual determinations	Average
In 0.2 N HCl extract, using the A. T. Kirsanov method				
Sod-medium-podzolic soil; Antslaskiy district	17.8 16.8 17.1	17.2	17.1 17.2 16.7	17.0
Sod-medium-podzolic soil; Vyruskiy district	8.5 8.5 7.9	8.3	8.2 7.8 8.2	8.1
Sod-podzolic gley soil; Mustveskiy district	7.1 7.1 7.2	7.1	7.0 7.4 7.4	7.3
Sod-carbonate leached soil; El'Vaskiy district	8.5 9.0 9.0	8.8	8.8 8.6 8.6	8.7
Sod-saturated soil (on weathered Dictyonema shale); Khar'yuskiy district	12.1 10.5 9.0	10.5	10.8 10.5 10.5	10.6
Sod-alluvial granular soil; Vyruskiy district	7.2 7.0 7.2	7.1	8.1 7.6 7.7	7.8
In 0.2 N $(NH_4)_2CO_3$ extract, using the D. Gusseynov and P. V. Protasov method				
Thin humus-carbonate soil; Iykhviskiy district	8.5 8.5 8.5	8.5	8.7 8.7 8.4	8.6
Thin humus-carbonate soil; Iykhviskiy district	38.0 38.0 37.2	37.7	39.0 39.0 39.0	39.0
Same	33.8 33.2 33.2	33.4	35.2 35.4 36.0	35.5
Sod-carbonate thin soil; Khar'yuskiy district	17.0 17.4 16.6	17.0	17.2 17.7 17.6	17.5
Sod-carbonate thin soil; Iykhviskiy district	8.0 8.0 8.0	8.0	9.0 9.2 9.4	9.2

color because of its high content of sesquioxides (8) (Sample No. 24, 25, 26, 29, 74, 75, 206). Controlled experiments with true solutions of iron and aluminum salts show that these elements interfere with the potassium determination.

The iron and aluminum were removed from the hydrochloric acid extracts as follows: to 25 mm of 0.2 N hydrochloric acid extract were added drops of concentrated ammonia solutions up to a pH of 5.0 (as determined by litmus paper). On the following day the standing or filtered transparent colorless liquid was used in determining potassium by means of the previously-described photometer. Parallel

Table 2

Comparison of available potassium determinations by the flame and the chemical cobalt nitrate methods

ample No.	Soil	Horizon and depth, cm	Kirsanov method			Maslova method	
			In flame		Chemically	In flame	Chemically
			In 0. 2 N HC1	Precipitate			
24	Typical strongly podzolic forest soil	A_2B25—35	5,0	2,0	2,0	1,4	1,2
25		B_1 35—45	10,0	2,5	2,5	1,2	1,2
26		B_1 45--55	6,2	2,5	3,0	0,5	0,7
29		B_2 75--80	2,5	1,0	1,0	0,4	0,6
74	Typical strongly podzolic sandy forest soil	B_1 55—65	18,0	1,4	1,7	1,3	1,0
75		B_2 75—85	5,0	1,4	1,25	1,0	1,4
206	Sod-strongly-podzolic gleyed sandy plowed soil	B_1 40—50	4,2	1,4	1,7	1,0	1,2
207		B_2 50—60	2,5	1,8	2,0	0,9	1,0
470	Sod-strongly-podzolic gleyed sandy forest soil	A_1 4—13	8,7	7,7	7,2	5,8	5,4
88	Sod-weakly-podzolic clay loam plowed soil	A_1 0—23	14,0	14,0	13,2	13,9	12,1
89		A_2B 23—41	9,5	9,5	10,8	8,2	7,0
90		B 41—50	10,5	10,8	10,0	9,5	8,3
77	Sod-medium-podzolic sandy loam plowed soil	A_1 4—16	2,9	2,9	2,5	2,6	3,0
78		A_2 16—18	1,5	1,7	1,3	0,6	1,0
2239[a]	Sod-carbonate typical medium-thick clay loam plowed soil					31,2	29,0
231[a]	Sod-carbonate typical thick coarse clay loam plowed soil					61,2	55,0
226[a]	Sod-carbonate typical thin sandy loam plowed soil					8,4	9,7
230[a]	Sod-carbonate leached coarse clay loam plowed soil					46,4	40,5

[a] By the Gusseynov-Protasov method.

lote: Comma represents decimal point.

chemical determinations of the potassium in a 0. 2 N hydrochloric acid extract by the cobalt nitrite method produced results close to those obtained by the method described in this article. In weakly colored 0. 2 N hydrochloric acid extracts, the iron and aluminum hinder the determination of potassium to a lesser degree (Sample No. 207), and in some samples (88, 89, 90, 77, 78) they are not noticeable. In determining the potassium in hydrochloric acid extracts by the previously-described photometer, it is recommended that the iron and aluminum be removed by the indicated method.

The available potassium may be determined by this photometer without preliminary preparation in an extract of 1 N ammonium acetate (by the Maslova method) and in 0. 2 N extracts of ammonium carbonate from carbonate soils (by the Gusseynov-Protasov method).

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A PORTABLE MECHANIZED AUGER FOR TAKING SOIL SAMPLES

N. A. DIMO

Soil scientists working in the field or at experimental stations require completely or partially mechanized equipment. Instruments for taking soil samples, particularly augers, have not been completely satisfactory. For this reason it is useful to publish descriptions of newly-improved rigs. In this regard, the Syun-i auger described in Pochvovedeniye No. 7, 1956, is a good example of information on the use of this equipment in the Chinese People's Republic.

In working with engineers Aslamazyan and Mgebryan, I have constructed a double-shaft auger. This auger may be used to withdraw cores enclosed in a casing from the soil. These cores may be theoretically of any diameter and depth and may be removed without destroying their structure. At present, calculations and working drawings have been made for the extraction of cores 15 cm in diameter and 40 m in depth. The entire process of removing such a core takes 40 to 50 minutes. The core may be weighed and then half of it may be exposed for the removal of samples and for describing the soil profile. In a number of cases, the cores may be used without removal of the casing in order to study a number of soil properties, particularly those involving water-movement.

An article on soil augers appeared in Pochvovedeniye No. 5, 1956. The auger is attached to an apparatus carried on the operator's back; it is run by a two-speed 2-1/2 horsepower gasoline motor (Fig. 1). The power is transmitted to a tapered box located below (the transmission) through a centrifugal coupling and a flexible transmission cable. The auger is attached to the transmission by means of a coupling (adapter) and an arresting device (connecting piece), so that the auger may be very easily connected and disconnected. The weight of the entire apparatus is 16 kg.

Three types of augers have been developed (see Fig. 2). The total length of the auger and handle is 105 cm; rods 90 cm in length may be attached to lengthen the auger so that samples may be taken from great depths. The rods and augers are marked at every 15 cm. The upper end of the auger is slightly tapered so that the auger may be easily removed from the hole in the ground.

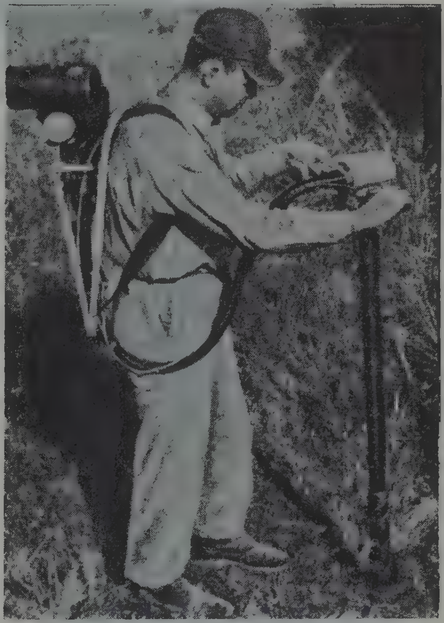

Fig. 1. The mechanized auger for taking soil samples, shown in operation. The $2\frac{1}{2}$-horsepower motor is capable of being used even in the most sticky clays.

The auger equipment was tested on two different soils in the eastern part of Texas. The tests were made at Boswell in an A horizon consisting of clay with fine sand down to a depth of 7.5 to 12.5 cm above a B horizon consisting of plastic fine-textured soil, and at Lackland on fine friable sand more than 180 cm thick. In each soil about 3 holes were drilled to depths of 180 cm; this involved drilling to remove samples from 15 to 30 cm intervals, extraction of the auger from the hole, removal of the sample from the auger and cleaning of the auger before each new drilling. A single extension was used for deeper samples (total depth 195 cm).

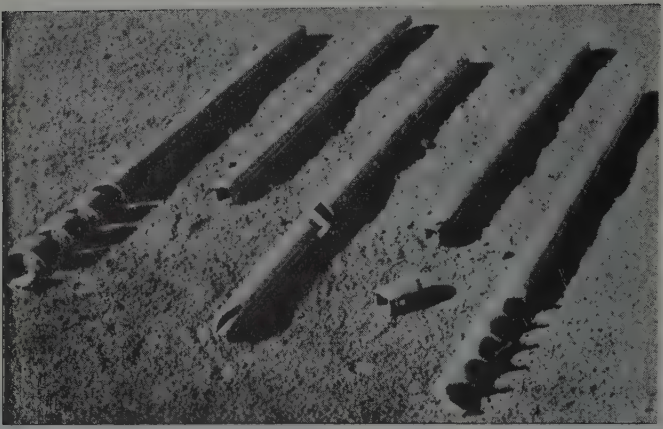

Fig. 2. Three reversible augers. They are $2\frac{1}{2}$ inches in diameter and 12 inches in length. The spiral auger (at left) is intended for use in medium- and coarse-textured soils with moisture between the field capacity and the wilting; the flap valved (riveted) auger (in the center) is intended for dry sands; and the screw auger (at right) is for use in especially plastic clays, shales or sticky soils.

The spiral auger was used in the Boswell soils, and a flap-valve (riveted) auger on the sandy soil at Lackland.

These augers removed samples from the holes with remarkable ease and rapidity (5 to 10 minutes). The samples were much easier to remove even from the fine clay subsoil at Boswell than by the ordinary hand augers. The drilling equipment was tested in other soils of eastern Texas as well; these included soils with a considerable amount of gravel. With the exception of the test in rocky soil, satisfactory results were obtained everywhere. Workers experienced in taking samples stated that the operation of this equipment was easier and more rapid than that of the ordinary hand auger, and that it could be used under conditions in which the hand auger failed to operate. The soil structure was not preserved in the samples removed by the simpler auger. Thus; in cases in which it is necessary to obtain samples with undisturbed soil structure, this equipment may be used to drill down to any depth, after which core samples with undisturbed structure may be removed with the hand auger.

CHRONICLE

MARIYA MIKHAYLOVNA KONONOVA - IN HONOR OF THE SIXTIETH ANNIVERSARY OF HER BIRTH

Editorial Staff of Pochvovedeniye
V. V. Dokuchayev Soil Institute, Academy of Sciences, USSR

During the past year Mariya Mikhaylovna Kononova, who is well known to a wide circle of soil scientists and biochemists, celebrated an important date -- the 60th anniversary of her birth and the 33rd anniversary of the beginning of her work as a scientist.

Mariya Mikhaylovna was born on August 18, 1898 in Orenburg into the family of a civilian employee. Upon graduating from the Orenburg Gymnasium for Girls in 1918, she was matriculated in the Voronezh Agricultural Institute. Thereafter, after a two-year interruption (in 1920 to 1921, when she served as a volunteer in the liaison section of the 1st Army on the Turkestan front) she transferred in 1921 to the faculty of mathematical physics in the State University of Central Asia; she was graduated from the latter in 1925 after specializing in plant physiology and microbiology. Upon completing the university course in this department, M. M. Kononova was awarded a postgraduate fellowship.

Her specialization during her student years under Professor A. V. Blagoveshchenskiy, who is well known for his papers in the field of plant physiology and biochemistry, her simultaneous work in the organic chemistry laboratory under the direction of Professor S. N. Naumov, and her post-graduate studies under the direction of Academician V. L. Omelyanskiy, have all contributed to the development of Mariya Mikhaylovna as a biologist of great and versatile abilities. In addition, her great interest in the lectures given by N. A. Dimo, soil scientist and member of the V. V. Dokuchayev Institute, whose course she took as a student, directed her efforts into the field of problems connected with the study of soils. Thus it was no accident that M. M. Kononova devoted her first scientific paper and all her further researches to the study of biologic processes in the soil.

Upon completing her University studies in 1925, the future post-graduate fellow, M. M. Kononova, became a staff member of the newly-organized Ak-kavak Experimental Station, where she began her studies of the microbiological processes taking place in sierozems. She was the author of the first definitive papers on the soil microbiology of Central Asia; on the rich content of aztobacter in irrigated sierozems; on the high energy of nitrification; on the value of sowing alfalfa in order to restore the level of organic nitrogen in sierozems; on the peculiarities of the microflora in the soil of rice fields; etc. The results of these studies, which have been widely used up to the present time by Central Asian microbiologists, soil scientists and agronomists, were published by

M. M. Kononova in a number of articles and in a special monographic collection (published in 1929).

In 1932 Mariya Mikhaylovna became associated with Professor I. V. Tyurin in the V. V. Dokuchayev Institute, Academy of Sciences, USSR, where she has been working continuously for the past twenty-six years, concentrating her efforts on studying the problems connected with soil humus. Her first years were devoted primarily to questions of methodology; after the Institute had been moved to Moscow, M. M. Kononova pursued her investigations in two directions; that of the biochemistry of humus formation and that of the processes involved in the transformation of the organic substances in the soil as a result of agricultural cultivation (in the Transvolga area and in Central Asia). The results of these investigations were presented in the form of a dissertation for the degree of Doctor of Biological Sciences, which was awarded to her in 1943 by the State University of Central Asia.

Since 1945, M. M. Kononova has been director of the Laboratory of Biochemistry and Soil Biology of the V. V. Dokuchayev Institute, Academy of Sciences, USSR; in carrying on her investigations, she has extended them to include the study of the nature and structure of the humus substances in the soils of the Soviet Union. It is difficult to encompass within the brief space of this note even the main results of Mariya Mikhaylovna's various investigations and the conclusions she has arrived at in the field of soil humus.

Her principal theses are as follows:

1) A study of the humus formation under natural conditions and in special experiments leads to the inescapable conclusion that humus substances are formed in numerous ways; the sources of humus include the various plant substances which have been subjected to complex processes of biochemical transformation.

2) Microorganisms not only cause the decomposition of the original organic material, but also play a very important role in synthesizing the molecules of humus substances; which takes place in the presence of oxidative ferments (phenoloxydase), which are secreted by many groups of microbes.

3) A comparative study of the nature and the structure of the humus substances in the principal soils of the USSR (by means of chemical methods, X-ray analysis, infra-red spectroscopy and chromatography) has led M. M. Kononova to conclude that there are many varieties of humic acids and that they change in regular fashion (becoming more complex) in a number of soils from northern podzolic soils to chernozems, with a certain simplification of the molecular structure in chestnut soils and sierozems. In this connection, there can be no doubt as to the function of humic acids in various soils; in podzolic soils particularly their action is similar to that of fulvic acids, which they resemble closely in nature.

4) Systematic investigations of the transformation of organic substances in the soils of various zones of the USSR, carried out both by M. M. Kononova herself and by her colleagues, have made it possible to discover the specific features in the processes of accumulation of organic substances under perennial grasses and their decomposition after the vegetative cover has been plowed under. These cycles of accumulation and decomposition of the organic substances are of great importance in solving numerous problems in agriculture associated with the rational use of the perennial grass covers under various soil and climatic conditions.

It is characteristic of Mariya Mikhaylovna's scientific creativeness that she has always concentrated her efforts toward the solution of key scientific problems and continually sought for new means and methods of investigation.

She presented the most important results of her investigations and of her study of the literature in her monograph on "The Problem of Soil Humus and the Present Tasks Involved in Its Study," published by the Academy of Sciences, USSR, in 1951.

For this monograph, in which she developed the ideas of some of the most outstanding soil scientists -- V. V. Dokuchayev, P. A. Kostychev, V. R. Vil'yams, and other Soviet scientists -- M. M. Kononova was awarded the V. V. Dokuchayev Prize in 1952. This monograph became widely known both in the USSR and abroad, was translated into Chinese and Polish, and was published in a new edition in the German Democratic Republic (in 1958); thus it has contributed to spreading the ideas of Soviet soil scientists among foreign scientists.

M. M. Kononova has not carried on any systematic teaching activity; nevertheless her lectures on soil microbiology in the State University of Central Asia, in the Agricultural Institute, her specialist course on the problem of soil humus given in the Moscow State University, and her numerous reports on various subjects have been highly praised by her listeners both for their content and their mastery of exposition.

Mariya Mikhaylovna has held numerous regular consultations with workers in central and especially in field organizations in outlying districts; she has aided numerous scientific workers in preparing their dissertations for the degrees of Candidate and Doctor.

In this brief review of M. M. Kononova's scientific work, mention must also be made of her great efforts in scientific organizations, particularly the All-Union Society of Soil Scientists and on the journal Pochvovedeniye. The editorial staff of the journal acknowledges with deep gratitude the enormous efforts which Mariya Mikhaylovna has devoted in recent years, as acting Chief Editor, to this journal of soil scientists of the Soviet Union, which also enjoys great popularity in other countries.

For her service in the field of science M. M. Kononova has been awarded the order of the Red Banner of Labor, as well as a medal for her outstanding work during the Second World War.

M. M. Kononova greets her 60th anniversary in full possession of her creative powers. It is hoped that Mariya Mikhaylovna will continue to enjoy good health and further successes in the development of Soviet soil science.

ANDREY VASIL'YEVICH SOKOLOV — IN HONOR OF THE SIXTIETH ANNIVERSARY OF HIS BIRTH

Editorial Staff of Pochvovedeniye
V. V. Dokuchayev Soil Institute, Academy of Sciences, USSR

The year 1958 marked the passage of sixty years of life and thirty-five years of activity in science, agronomy and related societies on the part of the great Soviet agricultural chemist and Doctor of Agricultural Sciences, Professor Andrey Vasil'yevich Sokolov.

A. V. Sokolov was born in 1898 at Balashov, in the Province of Saratov, into the family of a civilian employee. After his graduation from the Penza Gymnasium in 1916, Andrey Vasil'yevich entered the Department of Agriculture of the Petrov Agricultural Academy (now the Timiryazev Agricultural Academy), from which he was graduated in 1922. In the plant section of D. N. Pryanishnikov's Laboratory, Andrey Vasil'yevich studied the agricultural chemistry of soils, and in N. Ya. Dem'yanov's Laboratory he studied the chemistry of plants. He carried out his work for the diploma in the field of degraded chernozem under the direction of V. R. Vil'yams and A. N. Sokolov.

A. V. Sokolov began his own scientific work in 1923 at the Engel'gardt Agricultural Experimental Station. Even his earliest scientific investigations, published among the papers of the station (on adsorbed alumina, on the adsorption of P_2O_5 by the soil, on the methods of studying the physical properties of soils, on the decomposition of green manures in the soil, etc.) attracted the attention of a wide circle of agronomists.

From 1925 to 1930 A. V. Sokolov directed the work of the Department of Agricultural Chemistry in the Polesskaya Agricultural Experimental Station. Here he carried out a series of studies on the peculiarities of sandy soil; in particular, he suggested the microdynamic method of studying soil fertility, which threw new light on a number of problems involved in the interaction between fertilizers and soils.

In 1930 Andrey Vasil'yevich was invited to Moscow to take part in the work of the Scientific Institute of Fertilizers of VSNKh, now the Scientific Research Institute of Fertilizers and Insecto-fungicides (NIUIF) and the State Committee on Chemistry in the Council of Ministers of the USSR. In this Institute A. V. Sokolov (from 1930 to 1937) carried out the duties of director of the Laboratory of Nitrogen and Mixed Fertilizers, and from 1937 to the present time he has been director of the Agricultural Phosphorus Laboratory. From 1938 on, A. V. Sokolov also worked at the V. V. Dokuchayev Soil Institute, Academy of Sciences, USSR, directing the work of the Laboratory of Agricultural Chemistry at the Institute. In addition, he has been a scientific consultant to the All-Union Institute of Forage Crops on problems involving the use of fertilizer in forage crops.

In NIUIF and in the Soil Institute of the Academy of Sciences, A. V. Sokolov has carried out extensive scientific investigations of fundamental problems in agricultural chemistry and in the application of fertilizers. A. V. Sokolov has published more than 150 scientific papers in the most varied fields of agronomy. Special mention must be made of the following monographs: "Plant Yields and the Distribution of Nutrient Substances in the Soil" (1947), "The Agricultural Chemistry of Phosphorus" (1950) —translated into Chinese and into the languages of the other democratic republics; the manual "The Greenhouse Method" (1938), "Methods of Analyzing Agricultural Plants" (1941); and also reference works: on fertilizers (NIU 1933), a reference work for agronomists (1934 and 1937), a manual for agricultural chemists (1940). Finally, he has participated in compiling and editing the methodological handbook: "Agricultural Chemical Methods of Soil Analysis" (1944, 1954), which has also been published outside the Soviet Union.

Andrey Vasil'yevich's work in the agronomic evaluation of various forms of mineral fertilizers, and in particular of the new forms of concentrated nitrogen and phosphate fertilizers, has been of great importance in providing a scientific basis for the selection of mineral fertilizers and for planning the work of the fertilizer plants of the USSR. Professor A. V. Sokolov, by means of his investigations, has shown the importance and the advantages of concentrated and mixed fertilizers, particularly in regard to their application under various soil and climatic conditions.

A. V. Sokolov has carried out his agricultural chemical work by means of the latest methods of investigation, particularly the isotope method; this has enabled him to draw a number of new theoretical conclusions in the field of the physiology of plant nutrition and the effectiveness of fertilization. His work on the chloriphobic and calciphobic plants has made it possible to determine the conditions for the most effective use of chlorine-containing fertilizers. In 1935 Andrey Vasil'yevich developed the means of using borax fertilizers in the sowing of legumes; this method has found wide use both in the USSR and in other countries.

Andrey Vasil'yevich has devoted a great part of his scientific researches to the problem of phosphate nutrition of plants and to the evaluation of various types of phosphorus fertilizers. He originated and developed the idea of granulated fertilizers and applied it to production; and he has also been an indefatigable proponent of introducing fertilizers into rows.

Andrey Vasil'yevich Sokolov has paid great attention in his investigations to problems of methodology. He has produced handbooks on the field and greenhouse methods of studying soils and has developed methods of determining the mobile aluminum and hydrogen in soils, and of the available phosphates in fluoride extracts, not to mention the biological-radiochemical method of determining the phosphate requirements of soils, and the method of fractional determination of phosphorus compounds in plants and elsewhere, which have been widely used and applied in laboratories of agricultural chemistry.

In post-war years A. V. Sokolov initiated the wide application of the method of radioactive isotopes in soil and agronomic investigations. By means of the radioactive isotope P^{32} he made a scientific evaluation of the existing chemical methods of determining available phosphates in the soil. His work in this field, which was reported to the Geneva Conference on the Peaceful Uses of Atomic Energy, is of great practical value in agriculture. The method developed by A. V. Sokolov of determining the proper use of phosphorus fertilizers, on the basis of a computation of the amounts of available phosphate by means of the isotope P^{32}, have made it possible to provide a factual basis for the introduction of phosphorus into the soil in areas of cotton, tea and sugar-beet, and to decrease the large amounts of phosphorus fertilizers that have been regularly used in such areas.

In a number of his papers, A. V. Sokolov developed D. N. Pryanishnikov's ideas on the problem of biological nitrogen in the agriculture of the USSR. In particular, he indicated the extent of nitrogen fixation by leguminous plants at various yield levels and under particular agricultural conditions.

A. V. Sokolov has always been an active supporter of the use of proper crop rotation and of the sowing of leguminous plants; he has decisively declared his opposition to the former ubiquitous use of the continuous grass system of agriculture.

A. V. Sokolov's various studies of the problem of the cyclical development of substances in agriculture, his elaboration of the scientific basis for the use of mineral and organic fertilizers, and his numerous works on methodology all constitute enormous contributions to agronomy in the Soviet Union, and are of great importance in raising the level of agricultural science and in introducing chemical principles into the agriculture of the USSR.

A. V. Sokolov has also initiated and directed studies on the agricultural chemical characteristics of the main soil groups in the Soviet Union.

He has also devoted much of his time and energies to the training of new agricultural chemists, and has trained a large number of specialists, doctors and candidates in agricultural sciences who are at present working in various cities of the Soviet Union. It would be hard to overestimate the value of A. V. Sokolov's activities in agricultural chemical societies and scientific organizations. It should be remembered that he founded many laboratories in agricultural chemical production. As early as 1930 to 1931 he suggested organizing agricultural chemical laboratories at the Machine Tractor Stations. A. V. Sokolov is Vice President of the All-Union Society of Soil Scientists, President of the Section of Agricultural Chemistry and Soil Science at the Moscow Palace of Science, member of the editorial staff of the journal Pochvovedeniye, and a member of the Council of Scientists of the V. V. Dokuchayev Soil Institute, Academy of Sciences, USSR, the Institute of Forage Crops and the Institute of Fertilization and Insecto-fungicides, a member of the governing board of the Section on Fertilizers of VASKhNIL, President of the Committee on Methodology of the Soil Institute, Academy of Sciences, USSR, and a member of the Council on Scientific Methods in the Ministry of Agriculture of the USSR.

A. V. Sokolov has initiated and organized all-union conferences and meetings on problems connected with plant nutrition, soil fertility, and agricultural chemical methods of studying soils and plants.

All Soviet agricultural chemists and soil scientists join his numerous friends and students in sincerely hoping that Andrey Vasil'yevich will continue to enjoy good health and to achieve great new successes in his work.

SOIL PHYSICS IN THE SCIENTIFIC RESEARCH INSTITUTE OF AGRICULTURAL PHYSICS

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At the time of the Great October Revolution 1917) work in the field of soil physics in Rus- ia was still in its infancy; investigations in nis area were being carried on only by indi- idual scientists, since the means and the pportunities for such work were extremely imited. During the 40 years of Soviet rule oil physics became a discipline of very great mportance in both science and practical work. t the present time, this branch of science is eing developed by groups of scientists: 1) in he Department of Soil Physics of the Soil nstitute, Academy of Sciences, USSR, 2) in he Department of Soil Physics and Meliora- ion, Moscow State University, 3) in the departments and laboratories of soil physics in a umber of specialized institutes, 4) in the nstitute of Fertilization and of Agricultural oil Science (VIUA), 5) in the All-Union Insti- ute of Hydrologic Engineering and Melioration,) in Soyuznikhi (Union Scientific Institute of Chemistry), 7) in the Saratov State University, tc. Soil physics is also being developed as an pplied discipline in a number of production nd planning bureaus.

The most extensive researches in soil phy- ics are being carried on in the Scientific Research Institute of Agricultural Physics, which recently celebrated its twenty-fifth nniversary.

One of the central problems in soil physics nd agricultural physics as a whole is that of he soil structure. Many of the physical prop- rties of the soil are derived from this, since hey are functions of its structure.

From the very beginning of its activity, the nstitute of Agricultural Physics has devoted xclusive attention to the soil structure and its ormation. A. F. Ioffe has established the ecessity of determining the agronomic impor- ance of the soil's macrostructure. In this con- ection, shortly after the Institute's foundation, experiments were begun under field conditions o study the effect of the soil structure on the yields of various crops. A water-stable macrostructure was produced by means of special cements and appropriate treatment, areas with weakly developed soil structure being used as controls in the experiments. The experimental plots did not differ chemically from the control plots, since the latter were fertilized with the same quantities of nutrient substances, introduced with cement into the experimental plots (5, 16, 17). Experiments on sod-podzolic clay loam soils at the Leningrad Agricultural Institute (LSKhI) showed that the plots treated with resinous cement produced a considerably higher yield of barley (up to 61.3%) than the control plots. Similar results were obtained with other soils and with other crops (potatoes, tomatoes, peanuts, etc.). These results are in close agreement with V. V. Kvasnikov's well known data (9) on the relationship between crop yields and the degree of aggregation.

The Institute has carried out large-scale experimental studies of the processes of gas exchange in the soil. It has been established that samples of the same soil, of which one is composed of macroaggregates and the other is pulverized (dry), have the same rather high coefficient of diffusion which is fully sufficient for normal gas diffusion in the soil. The coefficient of diffusion decreases rapidly in the pulverized specimen with the increase in the amount of moisture, so that when the moisture content reaches the level of 35% of the soil's volume, it is smaller by several times. The same amount of water in the structured sample causes only a slow decrease in diffusion down to half the rate when the soil is dry. When the particle diameters range from 0.1 to 0.01 mm, the interstices between them easily retain water, which acts as a hindrance to the exchange of gases. This was very clearly shown in experiments carried out on models by M. K. Mel'nikova.

At the present time there are numerous data on the much smaller water loss by evaporation from fairly well structured soils (12, 14, 3).

Recently there has been an ever greater accumulation of data showing that the conditions for plant growth may be greatly improved, even on solonetzes and podzolic soils, by means of polymers which rapidly produce a favorable soil structure.

Very detailed studies have been made of all the factors involved in the production of soil structure in general and of water-stable macroaggregates in particular. Laboratory experiments on soil structure (Vershinin [5]) have shown the importance of drying and wetting, of freezing and thawing, of the disintegrating action of plant root systems, and even of insects and burrowing animals in the formation of the soil's macrostructure. Under the action of these agents, however, the soil's macrostructure does not become water stable. Direct experiments in the same laboratory have shown that bi- and trivalent cations (Ca, Fe) cause the formation of microaggregates only (no greater than 0.05 mm in diameter). Hence the contents of adsorbed cations may be governed only by the microstructural composition of the soil, but not by its macrostructure, as some investigators have thought up to the present time. The water-stability of the macroaggregates is determined primarily by the organic substances, mainly that of the humic fraction. It is enough to remove this fraction from the most water-stable aggregates of a chernozem soil in order to cause the macroaggregates to lose all their water-stable properties. Finally, cations bonded to the organic substance are of essential importance. Water-stability is produced when the humic substances are bonded to calcium, but not to monovalent ions (2, 13, 15).

It is well known that experiments in the production of a water-stable macrostructure by means of peat cements, sylvic acid salt cements and others were first begun at the Institute of Agricultural Physics. At the present time such experiments and investigations are being carried out in almost all countries of the world. The creation of synthetic structural formers has aroused particular interest because of the great successes achieved in the field of the chemistry of high-molecular compounds.

The latest experiments have shown that polymers, even in extremely small percentages (hundredths or even thousandths of a percent of the soil's weight) sharply increase the water-stability of the macroaggregates; at the same time only about one percent of peat cement is required to produce the same results.

Some of the other results of the investigations in soil structure are worthy of mention. A large amount of material has been gathered which shows that perennial grasses have a favorable effect on the soil's structure in general and on its water-impermeability in particular. This has been observed even in the Central Chernozem Region, where the yield of grasses is only average.

The Institute's investigations, as well as those by other authors, especially N. A. Kachinskiy and his students, have shown that in addition to the water-stability, the porosity of the macrostructure is an important agricultural factor. The Institute has collected data on the porosities of macroaggregates taken from various soil groups. Objective methods of determining the porosity of macroaggregates are beginning to be worked out.

Studies of the so-called moisture at the time of structure formation occupy an important place in the papers on soil physics in general and in those of the Institute of Agricultural Physics in particular.

This problem has also been studied by Vilenskiy (6), Ryzhova (14), and other scientists. It should be mentioned that a well-timed treatment of the soil at the moisture level of structure formation is still an extremely effective means of rapidly restoring the soil's structure. Papers by P. V. Vershinin (5) have thrown light on certain theoretical aspects of this phenomenon. The moment of optimal moistening of the soil is considered to be the condition for the optimal compression and rearrangement of particles into aggregates; in drier and moister ranges this condition is not fulfilled. On the other hand, experiments in the Vershinin Laboratory have shown that if aggregates which possess all the necessary features for water-stability (above all the proper amount and type of organic substance) are broken up mechanically, a water-stable structure may be restored by proper treatment of the soil.

This statement, which has been proven many times, has for some reason been subjected to a great deal of criticism on the part of certain agronomists and soil scientists. Nevertheless there is no doubt that this condition is widespread in nature.

The laboratories of the Institute have obtained a great deal of data from the field in regard to the moisture of structure formation and the maturity of the soil. Methods of determining this moisture in soils have been suggested.

In recent years an increasingly important place in the publications of the Institute has been occupied by the study of soil textures and the determination of all possible means of treating them in order to decrease the resistance to soil cultivation. In particular, a detailed study has been made of the soil's friction and adhesion in relation to the quality of the steel plow's surface (including different steels and different ethods of treating their surfaces), to the con-ant flow of soil against the surface of the ow, to the soil structure, etc. For this pur-ose a special instrument (dynamometer) has een designed which has greatly facilitated the ork of investigators in calculating the tractive orces. It may be expected that extensive in-estigations in this field will very soon be carried out. It is important, for example, to have urves for each soil showing the relationship f the specific resistance to its moisture, to he preceding agricultural crops, and to other oil characteristics. It would also be very nteresting to obtain data on the physical con-ition and the tractive forces of the soil in elation to the rate of cultivation. Similar nvestigations have already been included in he program of the Institute.

The Institute of Agricultural Physics is arrying out detailed studies of the heat balance f the soil (1, 13, 19, 11). This work has not nly thrown light on the theoretical aspects of he problem, but has also discovered new means f acting on the heat balance of the soil as a whole and on its individual components. Such xtensively used practices as soil mulching, or example, have been given a rigorous foundation in physics. The theory behind this practice s that the soil's reflectivity (the so-called lbedo) depends on the color of its surface, whereas its radiation is a function of its temp-rature alone.

The most detailed investigations have been made of the processes of heat transfer in soils - i. e., of all the possible means of heat trans-er throughout the soil profile. It has been hown both mathematically and experimentally hat the heat transfer in the soil through radiation depends to a considerable extent on the diameter of the particles and on their temperature. The larger the particles, the greater the role of radiation in the total system of heat ransfer in the soil. As one might expect, heat ransfer by means of convection is also very ntensive in soils made up of large particles at least those larger than 1 mm in diameter).

The development of reliable methods of determining the soil's heat constants has made it possible to go on to a detailed study of the aws and the relationships of these properties o the soil's dispersion, mineral content, density and moisture. The greater the moisture in the soil, the greater will be its heat conductivity. This relationship is particularly clear in the moistening of a dry soil; when the moisture is further increased, the relationship becomes less clear.

The staff of the Institute has carried out one of the first investigations of the soil's heat supply under field conditions, for forest belts in comparison to the open steppe, and for irrigated fields as compared to non-irrigated areas. The magnitude of each of its components was determined. Thus, for example, in an irrigated field only 10-12% of the radiation heat supply in summertime is lost to evaporation and the same amount to heat currents in the soil, whereas up to 80% of the entire radiation heat supply is lost to turbulent currents in the air. If one recalls that territories with insufficient moisture occupy enormous areas in the southern and southeastern parts of the Soviet Union, the nature of the local droughts in the steppes becomes clear. This relationship is especially distinct in dry, moving sands, where evaporation from the sand, because of the presence of a dry, protective layer, decreases to zero in several days, and the flow of heat into the soil is also negligible because of the dryness of the sand and its low heat conductivity; under these conditions almost the entire radiation heat supply is lost to turbulent currents in the air. This excess of heat has a very destructive effect on the crops in adjoining agricultural areas.

Detailed study of the heat supply should produce a new understanding of certain natural phenomena, result in new theories, and suggest methods of regulating the thermal conditions under which plants must live. A thorough understanding of the energy processes on the surface of the soil should make it possible to arrive at scientific measures for calculating the soil temperature from the air temperature, to make long forecasts of the soil temperature from the forecasts of the air temperature, and produce a reliable method of predicting frosts on the basis of hydrometeorological data. The latter method has undergone continuous improvements recently in the laboratory. A. F. Chudnovskiy has produced a simple and portable apparatus for automatically forecasting the temperature between evening and sunrise.

Detailed investigations of the water regime in the soil are being carried out under the direction of F. Ye. Kolyasev (16, 17, 13, 15), whose sixtieth anniversary was recently celebrated by the Institute. The following basic problems have been studied: 1) the soil-hydraulic constants and the methods of determining them, 2) the moisture movement through the soil and the quantitative determination of its rate of movement, 3) processes of evaporation, condensation and transpiration and possible means of regulating them, 4) the effectiveness of introducing water by furrows in obtaining high yields in the southeastern part of the country, 5) the possibility of making preliminary calculations of the main soil-hydraulic constants according to the soil compaction and the specific weight of the solid phase of the soil; these should be easy to determine experimentally, using soil models for this purpose. Some general features of the results of this work are described below.

The soil moisture movement has been

investigated by various methods. In the earlier stages this was done by using soil samples in pipes. By this means, a study was made of the rate of water movement as affected by gradients of temperature, moisture and compaction. Even in the first experiments, which were carried out as early as the 1930's, a method of screening was introduced to separate the liquid flow of moisture from the moisture movement in the form of vapor. Hydrophobic earth or fine metal screens were used for this purpose. The rate of moisture movement has also been studied by a special method using driers, which make it possible to record the desiccation of the soil sample from its saturated condition to the state of complete desiccation. Later on, methods of capillary moistening and determination of the dynamic unit surface were introduced in order to find the mechanism and the rate of moisture movement. Experiments on models in glass capillary tubes were carried out, to determine the mechanism of certain kinds of movements. At the present time new methods of electroosmosis are being used to study these problems. Much interest has been aroused by a method of determining the rate of evaporation from changes in the moisture of the air. All these investigations have served as the basis for the theory of differential moisture of the soil -- i. e., the theory which considers the rate of moisture movement to be a function of its content in the soil. Equations for the rate of moisture movement were derived for each type of movement. Thus greater precision was introduced into the equations for the height of capillary rise and for the water movement as affected by the force of gravity, the gradient of the electrical potential (electroosmosis), the temperature potential (thermoosmosis), etc.

This theory has served as the basis for suggesting measures of "hydrophobization" of the soil, of methods of treating the soil in the arid Southeast in order to retain the moisture in it, and of the determination of the regional characteristics affecting spring plowing in various zones of the country. Study of the mechanism of water evaporation from the soil has suggested a laboratory method of determining the main properties of the soil water from the desorption curve. In addition, the Institute has produced methods of calculating the main soil-hydraulic properties of the soil from data on its density and its specific weight.

The Institute has accumulated a large amount of material on the water supply in various soils under various cultivated crops, and on the water requirements of the grain crops on the dark chestnut soils of the Volga River area and on the Cis-caucasus chernozems of the Rostov oblast', on dry land and on areas which derive moisture through the water recharge and from the irrigated crops. These data confirm the idea that when the plants obtain moisture from the soil, the expenditure of moisture in the middle of the vegetative period may be determined by the magnitude of the radiation heat supply or by the magnitude of the evaporative capacity. This suggests new approaches to the problem of the proper time and amounts in irrigating crops.

For a number of years a detailed study has been carried on of the water regime and the water supply in the shifting sands of the Lower Dnepr River (7), which are overgrown with a mixed forest. This has been particularly important in connection with the growing problem of the reforestation of the sands. Experimental investigations have been made of all the forms of water supply, particularly of the height and the rate of capillary rise, the loss of water flow within the soil, the evaporation of water from the soil, transpiration by pine trees, and loss of water by evaporation from the surfaces of leaves after rain.

Contrary to the established views, the sands of the Lower Dnepr may contain as much as 200 mm of water in the 3-meter layer; the water of this entire layer will in many cases be available to the root system of the pine trees. Evaporation from the surface of the sands reaches noticeable proportions only immediately after a rain; the rest of the time it does not exceed several score millimeters in 24 hours and amounts to a total of 40-60 mm outside the summer period. Transpiration by pine trees, even with a full supply of water and on the very hottest and windiest days, rarely exceeds 3 mm in 24 hours. This is less than half the evaporative capacity according to the radiation heat supply. Data on the water supply have shown that with a normal growth of pine, the total moisture loss does not exceed 300-350 mm during the entire vegetation period; this is entirely compensated by the average annual precipitation during the season plus the supply of water in the soil. On the basis of this work, recommendations have been made in regard to the possibility and suitability of mass reforestation of the sands, which in most recent times has been considered a necessity.

The structure of the soil determines its air-water regime and, above all, the direction and rate of gas exchange between the air in the soil and the air in the atmosphere. Much attention has been devoted to the exchange of gases. On the basis of investigations made in other countries as well as of calculations made in the Soviet Union, it may be stated with full confidence that the soil's "respiration" is barely able to provide the necessary exchange of gases in the soil.

The diffusion of gases is the essential process in obtaining the necessary rate of exchange of gases.

Such ideas have been expressed in the West-n literature for a long time, and the published aterials have often been translated into Rus-an (see, for example, the monographs by een, Russel, Shaw and others). Neverthe-ss in Soviet educational and sometimes even cientific literature, the processes of gas ex-hange are still often considered to be the esult of the soil's respiration. A new step rward in this regard was made by the comple-on of a paper in mathematical physics on the nalysis of the processes of diffusion in the oil. This provided a basis in physics for the ethods of studying diffusion in relation to the oisture, the density, the structure and other roperties of the soil and for determining the asic laws governing the exchange of air (see e papers by Poyasov, 7, 13).

Very important achievements have been tained in the construction of instruments (4). number of instruments have been constructed r the measurement of various conditions overning the life of plants. It must not be for-otten that Soviet agricultural science and its ystem of experimental stations, especially the et of hydrometeorological stations, still lacks ufficient precision instruments. For this eason, one of the main aspects of Soviet instru-ent construction is the production of remote-ontrol equipment, operating as much as pos-ble automatically or at least with continuous ecording of data.

Semiconductors have recently begun to play n important role in Soviet instrument produc-on. These have been used in instruments de-gned for a great variety of purposes. The mperature of the soil and the air may now be easured to any desired degree of accuracy. here are also instruments for measuring the mperature and humidity of the air. These clude the radically improved Assman psy-hrometer, in which the two mercury thermome-ers have been replaced by semiconductors and e spring-operated ventilator by a small elec-ric motor. The wet-bulb thermometer is oistened automatically, and the small motor or passing air through the apparatus may be topped and started by remote control; as a esult the entire instrument operates by remote ontrol. This equipment has been of extremely reat importance in all investigations in which is necessary to measure the gradients of the ir humidity at various altitudes above the arth's surface.

The Institute has produced an instrument hich represents a great step forward in the ethods of investigation in agricultural physics. his is a semiconductor microthermometer for easuring the temperature of various plant rgans (leaves, stems, flowers, etc.). The nstrument is built around a small sphere or ead, 1 mm or less in diameter, made of semi-onductor material. This microresistor does not have a great lag, so that the equilibrium condition may be established rapidly and the reading may also be made quickly (in less than 1 minute). This instrument operates by contact: within a few seconds after it has been placed against the lower surface of a leaf, one may read the leaf's temperature. Thus it has become possible to make a simultaneous (synchronized) measurement of the temperatures of the leaf and the air, and to determine the difference in temperatures between them; this is of great importance in many investigations of plant physiology. An objective luxmeter has been developed which may be used to determine the exposure to light of plants in areas of exposed and covered soil.

Other instruments developed by the Institute have also aroused great interest. Enclosed needles and a gas analyzer have been developed in order to study the composition of the air in the soil under field conditions.

New methods have been suggested for evaluating the water-stability of the soil structure. P. V. Vershinin's instrument introduces an element of objectivity into the study of the dispersion of soil aggregates; by means of a photoelectric cell and a galvanometer, the time at which the dispersing of the sample ends and the degree of turbidity of the suspension may both be determined.

A new method of analyzing the water-stability of the soil has been recently suggested. This uses soil samples whose capillaries are thoroughly moistened in slowly moving water -- that is, under conditions most closely approaching the natural action to which the soil is subjected. Important data on the soil structure may also be obtained by studying the soil's water-stability. Thus the Institute has improved the Vil'yams-Savvinov instrument, which is now made entirely out of metal, and the analysis is made on specimens with undisturbed structure. Each instrument includes 20 cylinders for taking such samples.

A great deal of attention has been devoted to the development of various automatically operating instruments. Thus, for example, all the temperature- and radiation-measuring instruments operate with continuous recording of data. This has opened up the possibility of obtaining continuous records of many properties such as the temperature of the soil, the humidity of the air, transpiration by plants, the daily changes in radiation, etc.

There are thermo-signalling devices which put out a warning sound or light signal to indicate the approach of unfavorable temperatures in one object or another and the change of these temperatures in the required direction. All these instruments operate by remote control. Mass production has begun of dynamometers which automatically record the path traveled by a tractor and the work it does in cultivating the soil with the various tools attached to it. A furrow-measuring device is also being studied and developed -- this is an instrument which automatically records the average depth of plowing. At the present time three factories are already producing the instruments developed by the Institute of Agricultural Physics. It is hoped that in the year 1958 a large number of such instruments will enter production.

In spite of these well-known achievements in the field of instrument development, there is still no reason for being satisfied with what has been done thus far. Many phenomena, processes, and properties of the soil and of other objects of agricultural study are still inadequately recorded by present-day methods. For this reason the efforts toward the development and construction of instruments must be redoubled.

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THE WORK OF THE KIRGHIZ BRANCH OF THE ALL-UNION SOCIETY OF SOIL SCIENTISTS

N. K. BAZHENOV

The Kirghiz Branch of the All-Union Society of Soil Scientists was organized in May 1956; at the present time it includes 48 members.

Almost all the soil scientists and agricultural chemists of Kirghizia have become members of the All-Union Society of Soil Scientists.

Since the time of its founding, the Kirghiz Branch of the Society has held two general meetings jointly with the Department of Soil Science of the Academy of Sciences of the Kirghiz SSR. In the first session, nearly 100 specialists from 14 scientific and productive organizations participated. The following reports were heard by the members of the society: by G. I. Roychenko on "The Terminology and Systematic Classification of the Soils of Kirghizia;" and by A. M. Mamytov, M. S. Kurbatov, A. A. Zabegaylov, M. A. Zorin and L. I. Dashevkiy on "The Present State and Future Prospects of Soil Investigations in Kirghizia." It was recommended that the unified terminology and classification of Kirghizian soils contained in "A Systematic List of the Soils of Kirghizia" (1956) should be adopted. This published list is used as a guide to making soil maps.

It was reported to the meeting that in recent years in Kirghizia a great deal of work has been done in studying the soils of the Republic, in discovering the general laws governing the geographic distribution of the soils and in describing the main features of the various soil groups. It was also noted that these soil investigations have been characterized by a lack of coordination, an overlapping of work and a lack of unified methods. The meeting noted the main trends and prospects in the scientific research work done by soil institutes in Kirghizia, taking account of the tasks being carried out by each group of soil scientists.

At the second general meeting, the members of the Kirghiz Branch of the Society of Soil Scientists heard and discussed the following reports: by G. I. Roychenko on "A Soil Map of the Kirghizian SSR," and by A. M. Mamytov on "The Soil Regions of Kirghizia."

More than 60 persons from 15 organizations took part in the meeting and discussed the reports. The meeting approved the "Soil Map of the Kirghiz SSR" produced by the Department of Soil Science of the Academy of Sciences of the Kirghiz SSR, and also approved the principles used in dividing the territory of Kirghizia into soil provinces, subprovinces, regions and districts.

These two general meetings of the members of the Society aided in organizing and strengthening the branch, in introducing a measure of coordination into the scientific and methodological work being done by the individual organizations represented in the Kirghiz Branch of the All-Union Society of Soil Scientists, and in directing efforts toward the solution of the most important of problems faced by the soil scientists and agricultural chemists of Kirghizia.

The members of the Society have published a number of important papers, including the "Systematic List of the Soils of Kirghizia" by N. K. Bakanov, M. S. Kurbatov, A. M. Mamytov, A. N. Rozanov, G. I. Roychenko and F. Ya. Fedichkin. A monograph on "The Soils of Southern Kirghizia" by G. I. Roychenko, and another on "The Soils of the Chuyskaya Valley" by A. N. Rozanov, A. L. Kil'chevskiy and M. S. Kurbatov are soon to be published.

Twenty articles on various problems of Kirghizian soil science have been published in periodicals.

Members of the Society in Kirghizia are carrying out extensive scientific research work on all of the various aspects of soil science.

Interesting data have been obtained from investigations of the high mountain soils of Central Tyan-Shan (by A. M. Mamytov) and of the mountain-forest soils of Kirghizia (by G. I. Roychenko and D. Kozhekov).

In 1957, in connection with the problem of utilizing the Bol'shoy Naryn River valley, extensive work was done in studying the soils of this river basin and in determining the areas of the land which were suitable for agricultural cultivation.

As a result of these investigations it was found that more than 50, 000 hectares were suitable for cultivation, and the general geographic distribution and main properties of the chief soils in the area of the Naryn River basin were determined.

Some members of the Society who are graduate fellows in the Department of Soil Science of the Academy of Sciences of the Kirghiz SSR -- A. G. Sukhachev, V. A. Makarenko, A. I. Obozov and Orozbayev -- are carrying out experiments under the conditions of the experimental station on the Aksay bogs, at an altitude of 3, 300 meters above sea level, to discover scientific means of utilizing high mountainous desert and semidesert soils.

Studies of the microflora in the soils of Central Tyan-Shan by E. G. Vukhrer, V. I. Sukhachev and R. M. Karabalayeva have discovered the total lack in these soils of bacteria fixing free nitrogen (Azotobacter), and the important role in humification played by the plant residues and fungus bacteria in the mountain-forest soils.

In 1958 a study was begun of the minor elements, nitrogen, phosphorus and potassium, and of the processes of salinization and swamping of the soils of Central Tyan-Shan.

In the spring of 1958, a group of soil scientists in the Agricultural Institute of the Ministry of Agriculture of the Kirghiz SSR began a project of large-scale soil mapping of the collective and state farms of the Republic. Plans have been made to map more than 1, 000, 000 hectares in the period from 1958 to 1962. The staff of the Institute, who are members of the Society, are studying the agricultural chemical properties of the soils of Kirghizia, and are developing scientifically based systems of fertilizing for various agricultural crops (sugar beets, grains, etc.).

A group of soil scientists in the "Kirghizgiprosel'khoz" Institute is carrying out a detailed investigation of irrigated lands for the purpose of soil melioration.

The members of the Kirghiz Branch of the Society are doing a great deal of work toward popularizing and carrying into practice the scientific achievements in the field of agriculture in the Republic. They have given more than 23 lectures, participated in 80 consultations, and published more than 15 articles in newspapers and journals. A popular scientific brochure on "The Soils of the Sysamyr Valley and their Utilization" has appeared in print. Soil and soil melioration maps of a number of areas in the Republic have been provided for agricultural and planning organizations. Certain members of the Society, including A. M. Mamytov, M. S. Kurbatov, G. I. Roychenko and S. M. Romanov, have taken part in a project to develop means of obtaining the greatest possible yield of agricultural products from 100 hectares of collective and state farm lands of the Republic.

The governing board of the Kirghiz branch has supervised the publication of material on the need for organizing a soil service in Kirghizia.

WORK ACCOMPLISHED IN 1957 BY THE YAKUTSK SECTION OF THE ALL-UNION SOCIETY OF SOIL SCIENTISTS

L. G. YELOVSKAYA

On January 1, 1958, the Yakutsk Section of the All-Union Society of Soil Scientists had 13 members.

During the course of 1957, individual members of the Society were occupied with direct investigations of the soils in various districts of Yakutia (of the Vilyuy group of districts and of Central Yakutia). These investigations resulted in the production of soil maps of the El'gayskiy and Nyurbinskiy state farms, of the soils of the Malaya Botuobuya and the Vilyuychan River basins (in the Suntar and Lena districts), a soil map of the Upper Vilyuy district and a general soil map of the entire group of Vilyuy districts. In Central Yakutia the members of the Society have made detailed soil surveys of individual collective farms and have made soil maps of five collective farms. All of these maps contain full descriptions of the soil's characteristics and recommendations for their agricultural use. In addition, preliminary conclusions were drawn and future plans made in connection with a detailed investigation of the soils of the Amgin, Lena and Yakutsk state farms. V. G. Zol'nikov, A. G. Yelovskaya, N. I. Musich and others have held consultations with local soil scientists in the Department of Soil Management of the Ministry of Agriculture of the Yakutsk Autonomous SSR.

In order to popularize and spread scientific knowledge of soil science and agricultural chemistry, the soil scientists in the Society have presented six reports and lectures on subjects concerned with the soils of the areas they have investigated and the principles of their agricultural utilization of these soils, and on the means of increasing the fertility of the soils in the western districts of Yakutia in connection with the creation of a diamond industry in this area, etc.

During 1957, thirteen articles appeared in print.

The members of the Yakutsk Section of the Society of Soil Scientists are carrying out experimental work on the utilization of virgin lands, testing the Mal'tsev system under the conditions of the Nyurbinskiy state farm, and studying the varying degrees of soil fertility under different methods of cultivation and fertilization at the Nyurbinskiy state farm. The members of the Society are also being aided in their scientific and theoretical work, and in raising their qualifications, through instruction given by V. G. Zol'nikov in the Ministry of Agriculture, on the subjects of soil classification in Yakutia, the application of the Mal'tsev system under the conditions prevailing in Yakutia, on problems involved in increasing the fertility of the soil, etc.

THE WORK OF THE TOMSK SECTION OF THE ALL-UNION SOCIETY OF SOIL SCIENTISTS

S. A. KOLYAGO

During the period of time since its foundation, the Tomsk Section of the Society of Soil Scientists has strengthened its organization and has also increased both the amount and the quality of its scientific research and production. The membership of the section has grown to 31.

In accordance with the work plan, there have been eight general meetings, and ten special sessions of the various units of the Section devoted to the reading of papers. The possibility was also suggested of holding one general meeting of the Section jointly with certain members of the Altay Section of the Society. The general meetings of the Section, in addition to organization questions, discussed eight scientific communications; the special sessions were devoted to the reading of 20 new papers on soil science and allied scientific disciplines.

Members of the Society (the staff of the Department of Soil Science at the University and of the Tomsk State Agricultural Experimental Station) participated actively in the work of the scientific conference of the Tomsk State University, held in honor of the 40th anniversary of the Great October Socialist Revolution. At the meetings of the section on soil science and agronomy, they communicated the results of their investigations in the fields of the genesis and geography of soils, soil management, agricultural chemistry and agronomy. These communications were highly rated by those who attended the conference.

During the summer of 1957 members of the Soviety -- the staff of the Department of Soil Science -- engaged in expeditions to the field involved in the investigations of a number of districts in Siberia. A large-scale soil map was made and the regional characteristics and subdivisions determined within the northwestern part of the "Stolba" state preserve (under the direction of S. A. Kolyago). A more accurate regional subdivision of the Tomsk district was made and material was collected on the changes in the level of nutrient substances in sod-podzolic and gray forest soils within this area (directed by N. F. Tyumentsev). A regional soil subdivision was made of the Tyumen district and more accurate subdivisions made within the Omsk district (under the direction of N. S. Smetanin).

Field experiments (directed by A. Ya. Zirnitis) were made at the Tomsk State Agricultural Experimental Station on the effectiveness of liming and on the use of organic-mineral and organic fertilizers on gray forest soils under various types of vegetation.

The members of the Society continued their earlier laboratory investigations on the qualitative composition of the humus in the main soil groups of Siberia (Ye. I. Simonova), on the comparative study of the fertility of gray forest and meadow-chernozem soils of the Tomsk district (L. M. Burlakova), on the genetic and geographical description and agricultural evaluation of the soils in the southern part of the Tomsk district (Ye. M. Nepryakhin), and on determining the effect of mineral and organic fertilizers in increasing the yield and the forage value of red clover on gray forest soils (E. D. Kuznetsova).

Important work was done in rendering aid to production and in popularizing knowledge of soil science and agronomy. Twelve members of the Society (students at the University) took part in field investigations of the soil conducted by soil parties of the district and county organizations of the Agricultural Administration of Western Siberia. They constructed large-scale soil maps of areas totaling more than 100,000 hectares.

Two pamphlets have been published: "The Use of Fertilizers in Flax Cultivation in the Tomsk District," By N. F. Tyumentsev and T. P. Slavnina, and "An Estimation of the Effectiveness of Using Manure," by N. F. Tyumentsev.

A number of magazine articles have been published on problems involved in increasing the productivity of agriculture in the Tomsk district. Twenty-three scientific papers and 12 articles have been prepared and published in both local and central presses. Numerous consultations have been held and more than 30 lectures have been given on problems of soil science, land management, agricultural chemistry and agronomy.

THE ACTIVITIES OF THE AZERBAYDZHAN BRANCH OF THE ALL-UNION SOCIETY OF SOIL SCIENTISTS

G. A. ALIEV

In 1957 the organization committee of the Azerbaydzhan Branch of the All-Union Society of Soil Scientists conducted a drive for new members and collectives, publicized scientific achievements in the field of soil science and agronomy, and participated in the development of proposals concerning the organization of a soil science service under the Ministry of Agriculture of the Azerbaydzhan SSR. Reports and lectures were organized for members of the Society and texts of reports prepared by the Society members for reading at the All-Union Soil Scientists Congress were discussed.

At the end of 1957 the number of active members in the Society reached 65.

A soil science service was organized under the Ministry of Agriculture of the Azerbaydzhan SSR with the active participation of the branch organization committee. The members of the Society took it upon themselves to render daily assistance in scientific methods by compiling large-scale soil and agricultural chemical maps of the kolkhozes and sovkhozes of the republic.

Reports were presented by the members of the Society at republic scientific conferences and meetings: G. A. Aliev -- at the Inter-Republic Conference on Soil Erosion and at the Transcaucasus Conference on Conservation of Natural Resources; K. A. Alekperov, A. N. Iziumov, and others -- at a meeting on soil erosion; B. M. Achaev, V. R. Volobuev, and R. V. Kovalev -- at a conference at Moscow State University on soil regionalization of the USSR; V. R. Volobuyev and D. M. Guseynov -- at the All-Union Conference of Soil Scientists and Agricultural Chemists.

The following reports of society members were heard at general meetings: "The Use of Gamma Rays to Determine Soil Density" by S. I. Dolgov; "Soil Observations Made During a Trip Through Southern China" by S. V. Zonn; "Some Soil-Geographic Observations Made During A Trip Around Europe" by G. A. Aliev; "Results of the International Congress of the Soil Science Society" by V. R. Volobuyev; "Melioration Conference in the USA" by V. A. Kovda; "Results of the Conference at the USSR Ministry of Agriculture on Increasing the Effectiveness of Fertilizers" by D. M. Guseynov and R. K. Guseynov.

A soil map and the legend to a soil map of the Azerbaydzhan SSR were reviewed and reports were prepared for the soil scientists' congress.

In addition, theses of a report were prepared and presented at a meeting of the II and IV Committees of the International Society of Soil Scientists (Hamburg) and at a conference on irrigation by sprinkling called by the VI Committee of the International Society of Soil Scientists (Copenhagen).

Members of the Society presented popular science articles and reports in the republic journals and newspapers and on the radio and conducted a great deal of activity among the kolkhozes. They gave lectures and published individual articles in the district newspapers.

THE WORK OF THE KAZAN BRANCH OF THE ALL-UNION SOCIETY OF SOIL SCIENTISTS FOR 1957

A. V. KOLOSKOVA

The Kazan Branch of the All-Union Society of Soil Scientists is composed of 28 specialists who work in the Kazan Branch of the Academy of Sciences, the State University, an agricultural institute, and in a soil group of the Administration of Land Management and Crop Rotation of the Tatar Ministry of Agriculture.

In 1957 the activities of the branch proceeded along these lines: 1) strengthening of organizational work; 2) conducting general meetings with discussions of a series of problems pertaining to increasing soil fertility; 3) organizing consultations with commercial establishments by the efforts of the Society members;) popularizing soil science.

The following reports were heard and discussed at general meetings: "The Water and Nutrient Regime of a Gray Forest Soil Under Corn" by R. K. Dautov and "Seasonal Dynamics of Certain Elements of a Fertilizer in Gray Forest Soils" by M. A. Korshunov. A report by M. F. Kurochnik, Chief of the Soil Detachment of the Administration of Land Management and Crop Rotation of the Tatar ASSR Ministry of Agriculture, entitled "The Industrial-Genetic Soil Classification of the Soils of the Tatar ASSR" was discussed at two lengthy sessions at the branch office in December 1957.

The members of the Kazan Branch of the Society systematically consulted commercial stablishments and organizations and certain Republic kolkhozes on problems of method and of the use of fertilizers, cultivating the soil, the roles of microelements, forage cultivation, cultivation of forests to protect fields, erosion control, etc. in order to increase soil fertility.

In 1957 the Society members prepared 20 scientific articles for publication. To popularize soil science and particular agricultural practices for increasing soil fertility, the members of the Society prepared a series of works for publication: "Soils of the Tatar ASSR" by A. Sh. Fatkullin in the Tatar language, "Agricultural practices of Cultivating Perennial Grasses, " by A. A. Kapitonov; "Field-Protecting Forest Belts as a factor in Increasing Soil Fertility" -- a monograph by M. A. Vinokurov, R. K. Dautov, and A. V. Koloskova; and the already published brochure "The Utilization and Cultivation of Garden Soil" by P. V. Grishin. At the present time a group of authors under the leadership of Professor M. A. Vinokurov is working on a compilation of monographs entitled "Soils of the Tatar ASSR. " An interregional soil-agronomic conference is planned for the end of 1958 and the beginning of 1959.

The Soil Group of the Administration of Land Management and Crop Rotation of the Tatar ASSR Ministry of Agriculture conducted a soil analysis in six districts (completely in the Aktan'sh and Drozhzhanov rayons and partially in the Kalinin, Rybnoslovod, Budenov, and Alekseev rayons) for the purpose of making an inventory of the soil reserve of the Republic.

THE WORK CONDUCTED BY THE MEMBERS OF THE ALTAY BRANCH OF THE ALL-UNION SOCIETY OF SOIL SCIENTISTS IN 1957

N. V. ORLOVSKIY

In 1957 the soil scientists of the Subdistrict Administration of Land Management analyzed the territory of 56 kolkhozes in the rayons of Ust'-Kalman, Krasnoshchekov, Tret'iakov, Rodin, Zav'ialov, Kur'in, Zmeinogor, and Rubtsov. The quality of the soil survey, in comparison with previous years, was improved as a result of using an accurate new topographical base map. Before the field work began, a systematic list of the soils was repeatedly discussed. Certain agricultural-industrial characteristics of the soils and land were clarified in explanatory notes.

N. V. Orlovskiy reported on the organization of the Soil Science Service, fertilizers and soil control, and on conducting detailed soil surveys in the kolkhozes and sovkhozes of the Altay Kray at the subdistrict conference of scientific research agricultural institutions. The report was approved by the conference and forwarded to the subdistrict administration for practical implementation.

V. I. Kotel'nikov, L. O. Karpacheviskiy, and E. G. Chagin studied the qualitative composition of the humus, forms of nitrogen and phosphorus, the physical properties, and the water regime of the basic soil groups in the subdistrict suitable for tilling. This made it possible to make the existing overly generalized concepts of the agricultural-industrial properties of the subdistrict soils more accurate. Kotel'nikov's and Karpachevskiy's reports were heard at the Tomsk University conference where they were approved.

The soil science faculty of the Altay Agricultural Institute established a soil museum which exhibited the different soils of the Altay kray. The students' practical work is conducted in the museum and lectures are read to agronomists and land managers.

N. V. Orlovskiy participated in the development of a natural regional subdivision and a system of agriculture by zones of the Altay kray which is summarized in the work "Soils, Agricultural Practices, and Crop Yields." Field tests were organized on saline soils in the sovkhozes of the Shelabolikhin, Burlin, Rodin, and Pospelikhin rayons. At the present time the results of the tests may be recommended to production for verification.

M. A. Pikalov presented a theoretical basis for using superphosphate mixtures with soil and humus; he also developed the component ratios in these mixtures. These mixtures are recommended to vegetable farms for filling hotbeds and hotbed pots.

Evaluation of the materials presented is accomplished by hearing the reports at meetings and conducting a practical discussion of them. This assists the members of the society in their theoretical and practical work.

THE WORK OF THE OMSK BRANCH OF THE ALL-UNION SOCIETY OF SOIL SCIENTISTS FOR 1957

V. M. PRUDNIKOVA

A branch of the All-Union Society of Soil Scientists composed of 31 people was organized in Omsk in December 1956.

The members of the Omsk Branch of the All-Union Society of Soil Scientists are workers of the Omsk Agricultural Institute, the Siberian Scientific-Research Institute of Agriculture, and the Administration of Land Management (soil scientists, agricultural chemists, farmers, and workers in agricultural and forest melioration). During last year the following reports were heard and discussed at meetings: "Compiling a Soil Map of the Omsk Oblast'" by N. D. Gradoboev; "Soils of the Mariinskiy Forest Steppe and the Change in Their Composition During Cultivation" by S. S. Trofimov; "Some Problems of the Genesis of Solonetz Soils" by P. I. Krupkin; and "The Change in the Properties of Sod-Podzolic Soils Under Cultivation" by V. M. Prudnikova.

Members of the society (K. P. Gorshenin, N. D. Gradoboev, V. V. Bernikov, M. Z. Zhuravlev, and M. M. Inspektorov) participated in brigades and commissions in developing methods to ensure a crop yield from each hundred hectares of land (by district and by zone) and in the compilation of agricultural instructions for the development of new lands.

A soil map of the Novosibirsk Oblast' was compiled under the leadership of K. P. Gorshenin and those soil areas established as being suitable for development as virgin soil area were tabulated.

Witten and oral recommendations were presented as an aid to industry on the problems of developing virgin solonetz soils, irrigating vegetable crops in a suburban area and methods of cultivating the soil, and adding fertilizers under spring wheat and corn. Consultations on special problems with agronomists of machine and tractor stations, kolkhozes, and sovkhozes were held.

More than 25 lectures were given to regional and district agricultural workers on problems of soil science, the use of fertilizers, soil erosion control, crop rotation, and other problems of agriculture. The members of the Society published 25 articles and theses in various Central and Siberian scientific and industrial journals.

The scientific workers of the Omsk Agricultural Institute conducted research on the following problems; a comparative study of different methods of cultivating solonetz soils south of Omsk Oblast' with respect to the dynamics of the nutrients contained in them, and their water-physical and chemical properties (A. S. Migutskiy); a study of the microflora of solonetz soils (N. S. Ponomareva); some problems of the genesis of solonetz soils (P. I. Krupkin); the effect of soil compaction on physicochemical and biological processes (M. M. Inspektorov); a study of the water-physical properties of the soils of the arable portions of a suburban zone, the irrigation regime of vegetable crops, and methods of determining the minimum moisture capacity of soils (M. Z. Zhuravlev); establishing the effectiveness of mineral fertilizers on old-plowed and newly developed sod-podzolic soils and the effect of lime on a clover crop in fine-textured, old-plowed sod-podzolic soils (A. E. Vozbutskaia and V. M. Prudnikova); a study of the water-physical properties of peat bog soils as a function of the duration of their development (N. M. Goliakov); colloid variations of solonetz soils during desolonetzization and solodization (N. A. Kolesov); a study of the comparative effectiveness of microelements, with different methods of adding them, on the growth and yield of millet, Sudan grass, and sweet clover; the effect of mineral and organic fertilizers on the chemical composition and yield of wheat (A. Z. Lambin); the effect of fertilizers on the yield and chemical composition of corn in ordinary chernozems (E. D. Volkov). N. K. Boldyrev studied the diagnostics of plant nutrition and the grain quality of a spring wheat by a general leaf analysis. Ia. I. Chetin conducted work on Siberian larch in the forest steppe and the steppe zone of Western Siberia and Northern Kazakhstan.

WORK OF THE OMSK BRANCH

Scientific workers of the Siberian Grain Scientific Research Institute studied the following problems; the effectiveness of fertilizers on chernozems and sod-podzolic soils; a system of cultivating solonetz soils and the dynamics of their stickiness; the water-physical properties of soils by shallow plowing and plowing under a spring wheat; the composition of a grass mixture to improve the saline and bog soils of the forest steppe of Western Siberia.

The soil group of the Administration of Land Management (B. S. Akinfiev -- detachment chief) generally finished compiling soil maps of the kolkhoz land tenures.

Scientific workers gave reports at:

1) sessions of the division of biological sciences of the Academy of Sciences of the USSR in Novosibirsk and Irkutsk (K. P. Gorshenin) and

2) scientific conferences in Novosibirsk. Tomsk and Omsk (M. Z. Zhuravlev, V. V. Bernikov, N. K. Boldyrev, A. Z. Lambin, A. E. Vozbutskaia, A. S. Migutskiy, A. E. Kochergin, and V. M. Prudnikova).

GRIGORIY MIKHAYLOVICH TUMIN (1876–1957)

A. S. RADOV, G. A. SHCHUBIN, E. K. TOPILIN, P. P. BEGUCHEV,
A. N. GUDKOV, G. E. VEDENIAPIN, V. F. SHUBIN, G. F. RASKHODOV,
L. I. KAZAKEVICH, P. S. IVASHCHENKO, S. G. KONUROV,
P. F. AGAPOV, A. F. IVANOV, AND OTHERS.

Grigoriy Mikhaylovich Tumin, the oldest soil scientist of our country, a prominent scientist and the head of the soil science faculty at the Stalingrad Agricultural Institute, died suddenly on August 8, 1957.

G. M. Tumin was born in 1876. From 1902 to 1916 he studied soils in the Saratov, Smolensk, and Tamboy Oblasts', in the Stavropol kray, and in the Asiatic part of Russia. From 1916 to 1933 Tumin worked at the Tambov, Saratov, and Kamenno-Steppe Experimental Stations.

In 1924 he was chosen head of the soil science faculty at Voronezh Agricultural Institute and in the same year the title of professor was confirmed. From the beginning of 1946 until the day he died he worked at the Stalingrad Agricultural Institute.

G. M. Tumin always raised new questions and developed new methods of scientific research. He was the first to discover new subgroups of chernozem soils which are characteristic of all of the northern border areas of the chernozem zone of the European part of the Soviet Union. His works on drought control have great practical value for the agriculture of the entire forest belt of the Soviet Union especially the southeast. Grigoriy Mikhaylovich participated directly in the field investigations of a joint expedition of the Academy of Sciences to study the soils of the Stalingrad-Astrakhan' State Forest Belt Route for the selection of virgin and permanent fallow lands in Stalingrad Oblast', for newly organized sovkhozes.

The Stalingrad Agricultural Institute has lost an outstanding soil scientist of the Dokuchayev school in G. M. Tumin who devoted all his efforts and knowledge to the task of serving the beloved Motherland. The memory of Grigoriy Mikhaylovich Tumin will long remain in the hearts of his associates and the students of the Stalingrad Agricultural Institute.

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